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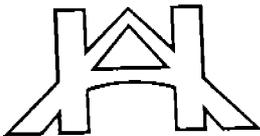
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## PROJECT REPORT

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## FEASIBILITY ASSESSMENT OF POTENTIAL APPLICATIONS/USES FOR NW TASMANIAN ORE



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Rev. 0, March 4, 1999

# HATCH

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March 4, 1999

Mineral Holdings Australia Pty. Limited  
Feasibility Assessment of Potential  
Applications/Uses for NW Tasmanian Ore

DISTRIBUTION

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Feasibility Assessment of Potential Applications/Uses for NW  
Tasmanian Ore

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## 1. EXECUTIVE SUMMARY

Mineral Holdings Australia Pty. Limited (MHA) holds retention licenses at Togaro and east of Redpa at Carbonate Hills in Tasmania. The areas under lease contain vast deposits of high quality marbleized dolomite, limestone and magnesia limestone. MHA has asked Hatch to do a preliminary overview of this resource and to assess various applications and uses for these ores.

The report also reviews the applications for "modified" carbonates from this resource in place of natural carbonates in metallurgical applications.

The report initially reviews the background and history of carbonate ore development and the applications. The carbonate ores are divided according to the mineralogy, chemical composition application and the end uses. The data are presented in the form of a triangle diagram.

The carbonates are divided into three categories in order to delineate their applications. The categories are limestone, dolomite and lime. The three applications for the individual carbonates have been identified, (direct, calcined or carbonate based chemicals), and order of magnitude volume requirements are indicated.

All areas which utilize carbonates are reviewed. These include construction aggregate, cement, metallurgical, chemical, paper, agriculture, glass, lime, refractory, etc. The possibility of replacing limestone with dolomite in steelmaking applications is also discussed.

For comparative purposes, the United States markets are assumed to be the standard for identification of applications and pricing. These numbers are then compared with Australia and the rest of the world.

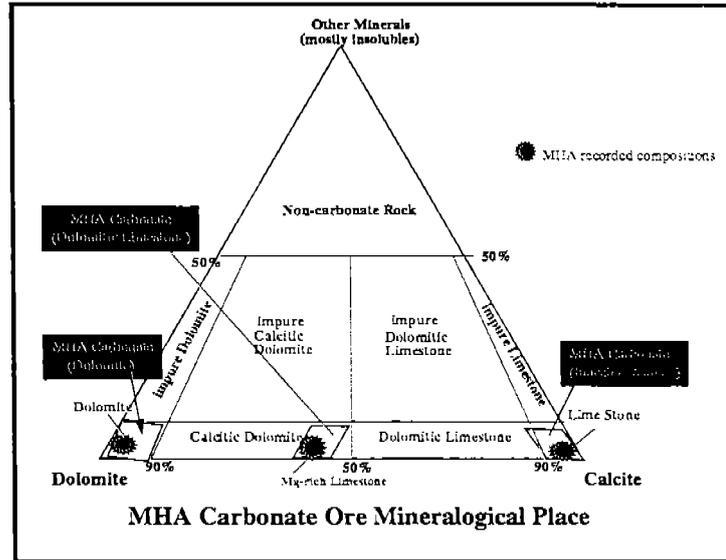
Calcined carbonates (or lime) is analyzed separately due to its vast application and amount of worldwide production. A brief review of a calcination method is presented and the variables involved in its production are given. Again, the main applications in the chemical, industrial, construction and metallurgical industries are discussed. The production from the USA is used as the benchmark.

The analyses of the Tasmanian carbonate samples have been compared to the specifications of other dolomites, limestone, and dolomitic limestones required for various end uses. Hatch has concluded that the Tasmanian carbonate ore is of high quality and potentially versatile. With effective marketing it can be used in all traditional limestone and dolomite applications.

The Tasmanian ore is compared to generally pure dolomite, limestone and dolomitic limestone and indicated on the diagram as is shown on the following page.



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Hatch has identified three options for marketing the Tasmanian ore. It could be marketed for direct applications in its present form with minimal beneficiation or it could be calcined (lime, dolime, etc.) or lastly, it could be marketed to small consumers who would generate their own products.

Due to the large size and excellent quality of the deposits this carbonate ore has potential for industrial applications. In addition, the low cost of energy, the existing infrastructure and its excellent location makes this a fine resource.

The magnesium rich limestone could be considered a good replacement for the dolomite/limestone mixture used as a flux in the steel industry.

It is possible that MHA can develop both internal Australian clients as well as off shore clients (primarily in Southeast Asia). We have highlighted the drawbacks to the external markets at the present time.

The two primary marketing options have been explored, low selling price (carbonate ore direct applications) and the high price route (calcined carbonate ores). It is Hatch's opinion that MHA should consider the latter route due to market versatility, production flexibility and varied applications. MHA should consider producing trial lots of calcined material and should proceed with a feasibility study for the installation and operation of a large calciner.



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## 2. SUGGESTIONS, RECOMMENDATIONS, AND CONCLUSIONS

Mineral Holdings Australia Pty. Limited has retention licenses at Togari and east of Redpa at Carbonate Hills in Tasmania. These licenses contain large deposits of very good quality marbleized dolomite, limestone and magnesia limestone. There is increasing evidence that there are large applications and markets. MHA wants to develop a Tasmanian operation near Port Latta to export the crypto-crystalline carbonate ores and at a later stage, consider the construction of a carbonate rock calciner at Port Latta, Tasmania.

Sample analyses were taken from the licenses and compared with the composition and the specifications of dolomite, limestone and dolomitic limestone required for various applications. Hatch concluded that NW Tasmanian carbonate ore is of high quality and potentially versatile. It can be used in most of the traditional limestone and dolomite applications with effective marketing.

MHA has three marketing options for the NW Tasmanian carbonate ore: market it for direct application as is with some beneficiation; or market after calcining as lime/dolime, etc.; or market it to various small scale consumers to generate their own products. MHA can choose any or all of the three routes or one of them depending on their marketing capability and interest.

The direct application method tends to have the lower selling price but without heavy capital investment. The only investment required in this area is the facility for carbonate ore grinding, screening and beneficiation to meet the market product physical specifications. Since the material is marbleized and crypto-crystalline, it is advantageous for MHA over other suppliers in milling and transportation (low fines and easy handling).

The calcined carbonate ore applications require further processing (calcining at various elevated temperature depending on applications), but command higher selling price. NW Tasmanian carbonates have proven excellent furnaceability, all-around versatility and low impurities, resulting in varied use and applications. The market is so broad that MHA should initially select only a couple of market areas and expand it later to other areas of application as conditions warrant. We agree with MHA that if there is sufficient interest developed in calcined carbonate ore, it is advantageous for MHA to construct a carbonate ore calciner at Port Latta and take advantage of convenient shipping rates and conditions.

The products that can be derived from NW Tasmanian Carbonate ore are: calcium oxide, calcium hydroxide, calcium carbide, magnesium carbonate, magnesia, and to a far lesser extent magnesium (through thermal reduction), and other indirect chemicals. These areas of NW Tasmanian ore application require extensive processing (and associated costs), but will tend to result in the highest value added to the raw material.

Steelmaking remains the largest single end user of the lime or carbonate rock. However, the serious economic problems affecting Japan, Southeast Asia, and the developing countries may have an adverse effect on the marketing of carbonate ore as a flux for steelmaking at the present time. In the long term, the flux consumption by the steel industry may flatten out or decrease due to industry changes in raw materials and flux usage. It is also well understood that when flux is partly replaced with dolomite material, it is good for the refractory linings of the blast furnace. Therefore, it may be advantageous to provide this flux as a one single rock, i.e. magnesium rich limestone (dolomitic limestone) of NW Tasmanian carbonate. Australia imports flux for its steel industry usage from Canada, China and Europe. Initially, MHA can market NW



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Tasmanian carbonates to these local Australian steel industries. The list of industries are given in the text and in the Appendix.

The Flue Gas Desulphurization (FGD) market may be the other area where MHA can concentrate the marketing of calcined NW Tasmanian carbonate. Phase II of the Clean Air Act, which takes effect January 1, 2000, and regulates small utility generating units in addition to larger units, will probably provide an additional boost for NW Tasmanian calcined carbonate.

The NW Tasmanian magnesium rich limestone lime or dolomitic lime can be marketed for neutralization of industrial waste or municipal waste of the local government.

The NW Tasmanian pure, low silica dolime or magnesia rich lime can replace quicklime in Bayer's process to produce alumina with good economics. Again, it is important that the testing at Q.A.L. be positive to market the product to alumina industries aggressively. MHA states that there are transportation advantages in shipping NW Tasmanian carbonate ore to this area. We agree that this has potential as back bulk loading of carbonates on alumina shipments to Point Henry, Gladstone, Weipa, Bell Bay, and the Pacific Rim. It was estimated that these plants consume around 1.5 million tonnes of carbonate materials calcined at many small plants.

There are six cement plants in Australia and both dolomite and limestone can be utilized on a selective basis. The list of plants are given in the Appendix.

The world's refractory industry is dominated by six major producers headquartered in Europe and USA. The NW Tasmanian carbonate is an excellent material for this application. The list of these industries is discussed in the text.

In addition, Australia has many coal mines. The NW Tasmanian limestone or dolomite fines can act as a coal dust blend to prevent mine explosions. The proximity of mines may be the key for this application. A list of coal mines in Australia is provided in the Appendix.

Non-ferrous metallurgy practices such as copper ore treatment, gold/silver recovery/treatment, uranium ore processing and others are potential areas for the calcined material. A list containing names of these companies is given in the Appendix.

Other markets such as sugar refining, pulp and paper, construction, and agriculture have generally captive producers, and penetrating this market may not be easy.

Following are our conclusions based on our analysis.

- The following main applications for NW Tasmanian carbonate ore have been identified. Based on their order of marketing importance, they are: as a flux in steelmaking, in non-ferrous metallurgy (e.g. Alumina industry, copper industries, gold-silver industries, etc.), in environmental use, in sanitation (neutralization), in the cement, refractory, construction, and agriculture - fertilizer industries.
- The NW Tasmanian carbonate deposits have tremendous potential for various industrial applications because of their high quality, vast reserve, large size, very low impurities, an accessible location - infrastructure and ports, and low environmental profile and low cost energy.
- MHA can develop both internal (Australian) as well as external clients (Japan and Southeast Asia) for their carbonates from NW Tasmanian.



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- There are two main options in marketing: the low selling price market for direct carbonate applications and the higher selling price market for calcined carbonate applications.
- The NW Tasmanian magnesium rich limestone may be a very good replacement for the dolomite and limestone mixture as a flux for the steel industries.
- ***MHA should consider entering the calcined product market due to its vast market, production flexibility, and versatility in applications. MHA should do a preliminary study and a feasibility analysis for installing a carbonate ore calciner in parallel to the further market research of the varied NW Tasmanian carbonate products.***

### 3. BACKGROUND

Tasmania is the small island state to the south of the southeastern corner of the mainland of Australia with an impressive record for metallic mineral production. Recently, there is also a considerable potential for commercialization of non-metallic minerals. Mineral Holdings Australia Pty Limited (MHA) has extensively explored the northwestern portion of the state. The exploration has led to the discovery of substantial quantities of magnesium and calcium carbonates to the west and southwest of the coastal town of Smithton. The carbonates of dolomite, magnesia enriched limestone, limestone and magnesite in this area are all marbled and therefore excellent for processing and transportation as ore with low dust. According to MHA, tests have proven that these ores are of high grade, with low impurities, excellent furnaceability to dead burning in the first pass in furnaces. Recently MHA sold its magnesite resources to Crest Magnesium NL of Perth, who are doing a definitive feasibility study to produce 90,000 tpa of magnesium metal.

MHA has retention licenses at Togari and east of Redpa, at Carbonate Hills. At Redpa, the dolomite is over 1000m thick and covers 1 km<sup>2</sup> area so there is a potential to extract 2 million tons per meter depth and the depth would appear to be limited only by practicalities of mining. In addition to this dolomite there is a deposit of approximately 100 million tonnes of dolomitic limestone/magnesium limestone or limestone in the eastern portion. At Togari, the dolomite deposit is of high quality with low silica, cover some tens of square kilometers, and have a very large potential resource to develop as open cuts. Assumed amount of recoverable carbonate ore is around 1600 million tonnes.

The market for carbonate ore is highly competitive and margin of profit is very small. Hence, success of carbonate industry is dependent on ready availability of infrastructure to mine, process and to transport the ore with a minimum cost. According to MHA, the ore and resources to process them are all located near seaboard and close to a highway which runs along the north coast and east of Smithton, roughly parallel to a railway. The highway encompasses the ports of Stanley which can accommodate 30,000 tonne vessels, Burnie (35,000 tonne), and Port Latta (bulk carriers of 110,000 tonne capacity). A mineral processing facility is located at port Latta. The iron pellet processing plant has 5 vertical calciners and is said to have a capacity of 2 million tonnes per annum. In short, according to MHA, carbonate ore is located near seaboard in sparsely populated, undulating, and cleared forest area near farming country without any environmental problems.



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#### 4. INTRODUCTION

Naturally occurring carbonates which include limestone, dolomite, chalks, marbles, and vein calcite, have been serving man in a varied number of roles since pre-history itself. Probably one of the most spectacular examples of man's association with this material can be seen in the great pyramids of ancient Egypt and Inca monuments of South America. Built in 4,000 - 2000 BC, these monuments were chiefly constructed of either rough-hewn nummulitic limestone-dolomite or hard burnt material of dolomite-limestone.

Carbonate rocks, which constitute some 15% of the earth's sedimentary crust and which have been deposited from Precambrian to recent times, provide raw material for more uses than perhaps any other rock type. Their global distribution is widespread and abundant although their exploitation and consumption, so typical of industrial minerals, is dependent upon their property requirements such as mineral composition, market demand, specific application, market proximity and ease of excavation. However, it is extensively exploited in almost every country for more industrial uses than perhaps any other mineral. In the USA, for example, around 75% of all ore or stone mined was accounted for by carbonate rock. But according to some industrial observers of the industrial minerals industry, carbonate rock/ore market is a highly competitive and cut-throat business.

Today, property requirements play a much more important role in dictating the choice of material for a particular application - and natural carbonate ores are by no means excluded from these directives. For example, carbonate rock in the construction industry have to meet various strength and aggregate size distribution requirements whereas purity, particle size distribution, mineralogy, and chemistry proves to be crucial in the more chemically and metallurgical oriented applications. Nevertheless, while industry continually strives to find materials which satisfy the various minimal technical and engineering requirements of a specification at the lowest possible cost, it is consistency of supply which tends to overrule most price considerations.

Although a carbonate deposit may be located close to markets and amenable to surface mining, it is the geology which ultimately determines the materials usefulness to various industrial and general applications. The environment of deposition is a significant factor in the eventual size and purity of the deposit, and subsequent mineralogical and tectonic changes will detract or enhance present-day physical, mineralitic, and chemical characteristics. With high grade carbonate ores (limestone, dolomite or calcitic ores), (classification and composition discussed later), it is the relative level of chemical impurities which usually restrict the material's use in certain applications. Silica and chert are the most common types of impurity occurring as disseminated grains or as concentrations of nodules, lenses, or beds. Organic matters and whole range of heavy metals can also cause problems in application. High concentrations of heavy metals are associated with hydrothermal deposition of other minerals such as galena, fluorite, and barytes. Physically restricting factors include rock weakness caused by poor cementation or lithification, or the result of post-depositional process such as jointing, faulting, fracturing, or brecciation. The theoretical combinations of physical and chemical restraints on a carbonate deposit are numerous but fortunately for us they are not economically significant - indeed the presence of regular jointing or bedding planes are a positive bonus to the extraction of dimension stone.

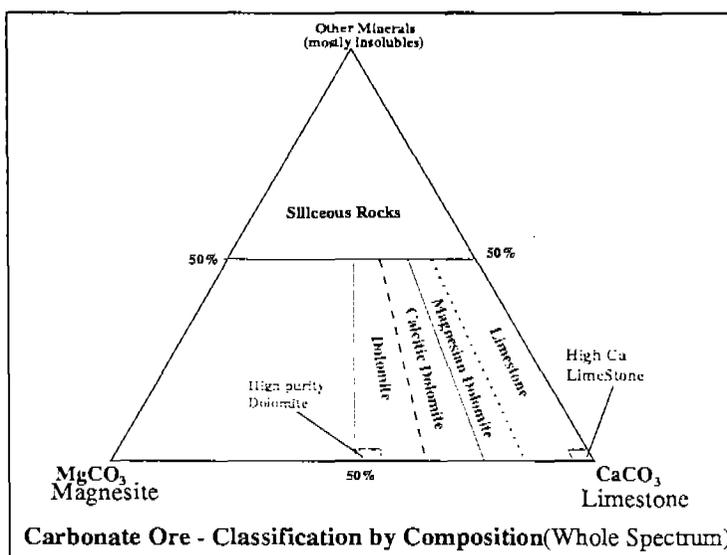


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**5. CARBONATE ORE CLASSIFICATION**

As an aggregate or chemical raw material, carbonate ore has certainly played an important role in the development of the industrialized world and for this reason a number of consumers involved have joined with government organizations to formulate particular physical, chemical, and mineralogical standards for certain carbonate raw materials in order to promote consistency of product performance. However, owing to the large scope of this enterprise only generalizations can be assessed and, in certain areas, particular regulations may prove too tight or lax for some consumers. For some applications, however, the usefulness of correct terminology is somewhat limited. For uses such as chemical and metallurgical, the proportion of magnesium carbonate to calcium carbonate is all important, and owing to the vast range of requirements sought by markets, chemical composition is considered more indicative of the rock potential than its mineralogical classification. As a general rule of thumb, rock referred to as "dolomite" or "calcite" or "aragonite" or "limestone" is often so-called simply owing to its being a source of dolomite or limestone for whatever use and regardless of the precise chemical composition. Bearing this in mind, this report looks at the principle areas where natural carbonates are employed and discusses varying specification requirements.

Carbonate ores are rarely monomineralitic in nature and this is where difficulties arise in naming of ores containing varying amounts of calcite, dolomite, and magnesite. The following diagram shows a mineralogical classification of carbonate ore/rock.

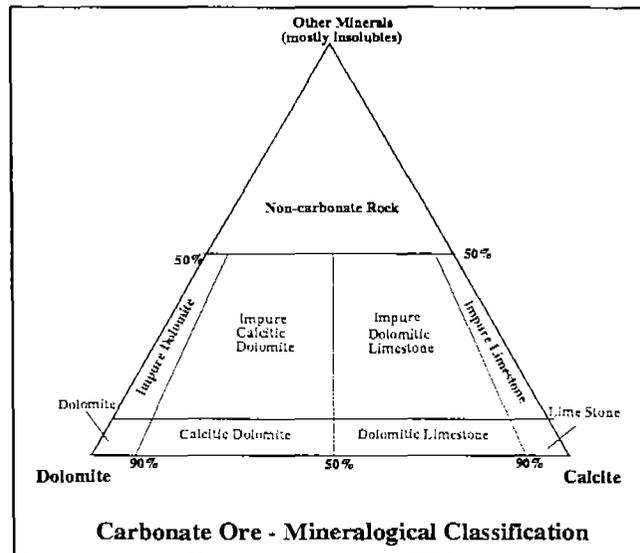


As shown in the diagram, the term dolomite is also applied to a rock type based on the dolomite mineral content. Generally speaking, definitions of dolomite and limestone based on their chemical composition vary from place to place. Hence the terminology used by the crushed stone industries is not always consistent with the nomenclature. The use of this loose terminology obviously leads to difficulties in keeping track of the amount of carbonate ore produced and consumed in the industry. Major carbonate ores are dolomite, limestone, magnesite, and variations in their compositions. Pure limestone and magnesite are two ends of the spectrum in composition and application (pure limestone being calcium carbonate, the pure magnesite being magnesium carbonate, and dolomite being a mixture of these two). However, magnesite is beyond the present scope of discussion. The above picture is only to give a total compositional placement overview of carbonate rock/ore.



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The carbonate ore triangle diagram given below covers only dolomite and limestone and excludes magnesite. The following diagram covers the broad spectrum of carbonate rocks. As shown in this diagram, if the siliceous impurities cross 50% of the composition, then the rocks are no longer called carbonate rocks and are useless for any application. From the broad classification diagram it is easy to conclude that division between these minerals is not well defined and some overlapping is unavoidable. In this diagram pure limestone is one corner of the triangle and pure dolomite is the other. Only the bottom portion of the triangle (say below 10% impurities) finds widespread industrial applications. As the insoluble impurities increase, the material becomes less and less useful, finally becomes non-carbonate rock. The uses for this material are discussed in a separate triangle diagram.



Pure limestone is calcium carbonate and has a chemical formula of  $\text{CaCO}_3$  with a molecular weight of 100.09 and a specific gravity of 2.71 - 2.93  $\text{g/cm}^3$ . Theoretically, pure limestone contains 56.1% CaO and 44%  $\text{CO}_2$ . Its hardness is 3.3 - 3.9 on Moh's scale. Impurities such as silica, galena, fluorite, chert, clay, heavy metals, organic matters are usually associated with limestone. In general, greater than 97%  $\text{CaCO}_3$  content is considered to be a pure limestone. Limestone is white in color when it is in pure form.

Pure magnesite is magnesium carbonate and has a chemical formula of  $\text{MgCO}_3$  with a molecular weight of 83.43 and a specific gravity of 3 - 3.2  $\text{g/cm}^3$ . Theoretically, pure magnesite contains 47.8 % MgO and 52.2%  $\text{CO}_2$ . Its hardness is 3.5 - 4.5 on Moh's scale. Natural magnesite almost always contains some calcium carbonate (as the mineral calcite) and iron carbonate (as the mineral siderite). Magnesite color varies from white when pure, to yellowish or gray white and brown.

Dolomite, the double carbonate of calcium and magnesium, is a compound rather than a mixture of calcite and magnesite. Pure dolomite has a chemical formula of  $\text{CaCO}_3 \cdot \text{MgCO}_3$  with a molecular weight of 184.4 and a specific gravity of 2.84 - 3.0  $\text{g/cm}^3$ . Theoretically, pure dolomite contains 45.7 %  $\text{MgCO}_3$  and 54.3%  $\text{CaCO}_3$ . Its hardness is 3.5 - 4.0 on Moh's scale and its crystal structure is rhombohedral. Pure dolomitic limestone has 30.4% CaO, 21.8% MgO, and 47.8%  $\text{CO}_2$ . Natural dolomitic limestone almost always contains some iron carbonate (as the mineral siderite), silica, chert, clay, shale, feldspar, etc. Dolomite color varies from white when pure, to yellowish or gray white and brown.

**HATCH****5.1 Definition of Terms Associated With Carbonate Ore/Rocks****➤ Limestone**

Limestone is calcium carbonate and has a chemical formula of  $\text{CaCO}_3$ . In general, greater than 97%  $\text{CaCO}_3$  content is considered to be a pure limestone. Limestone is white in color when it is in pure form.

**➤ Magnesite**

Magnesite is magnesium carbonate and has a chemical formula of  $\text{MgCO}_3$ . Theoretically, pure magnesite contains 47.8 % MgO and 52.2%  $\text{CO}_2$ . However, varied amount of calcite and other impurities are quite common.

**➤ Dolomite**

Dolomite, the double carbonate of calcium and magnesium, is a compound rather than a mixture of calcite and magnesite. Pure dolomite has a chemical formula of  $\text{CaCO}_3 \cdot \text{MgCO}_3$ . Theoretically, pure dolomite contains 45.7 %  $\text{MgCO}_3$  and 54.3%  $\text{CaCO}_3$ . Mostly associated with and often interbedded with limestone.

**➤ Dolomitic Limestone**

A limestone in which the mineral dolomite is conspicuous, but calcite is more abundant (10-50% dolomite, 50-90% calcite), or limestone that has been incompletely dolomatized.

**➤ Calcitic Dolomite**

A dolomite rock in which calcite is conspicuous, but the mineral dolomite is more abundant ( 10-50% dolomite, 50-90% calcite).

**➤ Dolostone**

It is a dolomite but a rock type. This name just differentiates mineral from rock.

**➤ Magnesian Limestone**

Generally the limestone with at least 90% calcite and the rest is dolomite. In some cases 10 - 23% dolomite containing limestone is also called Magnesian limestone.

**➤ Magnesian Dolomite**

If the content of the mineral is greater than 20% MgO, then it is called Magnesian Dolomite.



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➤ **Lime, Dolime, Dolomitic Lime**

A product derived from burning or calcining of limestone, dolomite or dolomitic rock containing CaO, MgO, etc. corresponding to their original carbonates. It is a general term that connotes only burned form of lime, usually quicklime, but sometimes hydrated or hydraulic lime. It may be calcitic, dolomitic or magnesian.

➤ **Dead Burned Dolomite, Refractory Lime, Doloma**

A specially sintered or double burned form produced at elevated temperatures (1450 - 1850 C) and further stabilized by the addition of iron that is chemically inactive and is employed primarily as a refractory for lining open-hearth steel furnaces.

➤ **Hard-burned Lime or Dolime**

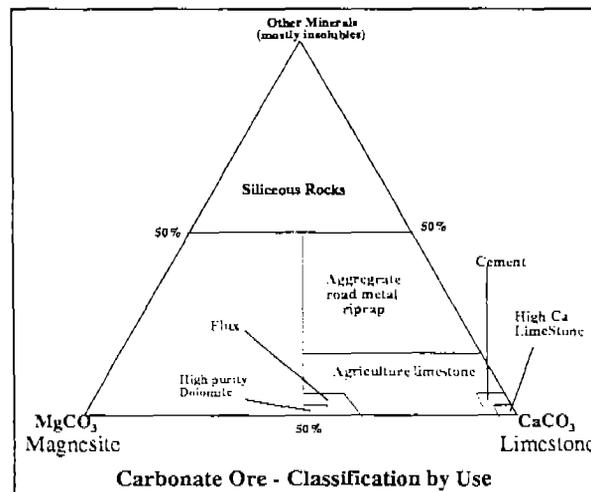
Material obtained by calcining at high temperature (1200- 1400 C), and is generally characterized by relatively high density and moderate to low chemical reactivity.

➤ **Quicklime**

Quicklime is a lime-oxide formed by calcining limestone so that carbon dioxide is decomposed off. It may be calcium, magnesian, or dolomitic and of varying degree of chemical purity.

**6. APPLICATION OF CARBONATE ORES**

There exists an extremely broad end use spectrum for carbonate ore. It is one of the largest raw materials (as in original or modified form) used in metallurgical and chemical industries. Since limestone and dolomite (as an ore) have maintained their specific identity in industrial applications, it is very useful to discuss their applications separately. The broad applications/use can be given in the following triangle diagram. However, uses are not restricted to these market areas but they are the best fit (uses) based on composition and value.

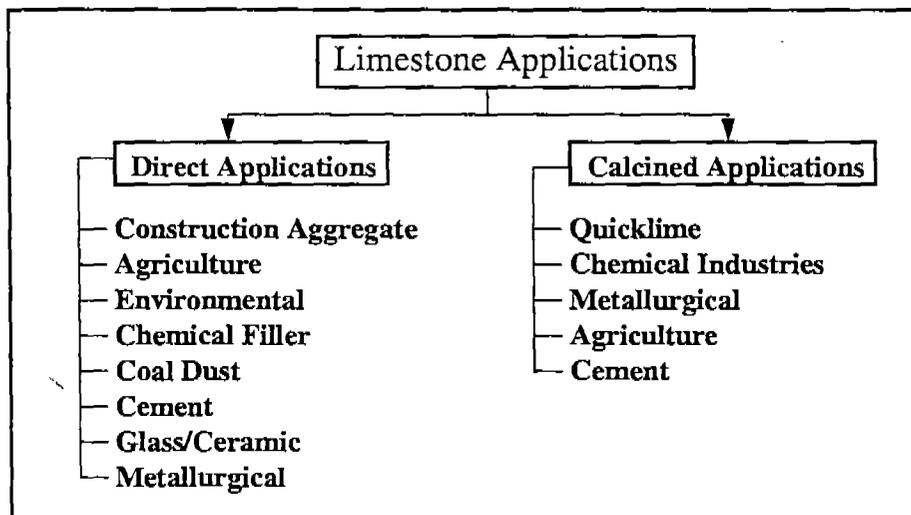




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## 6.1 Limestone

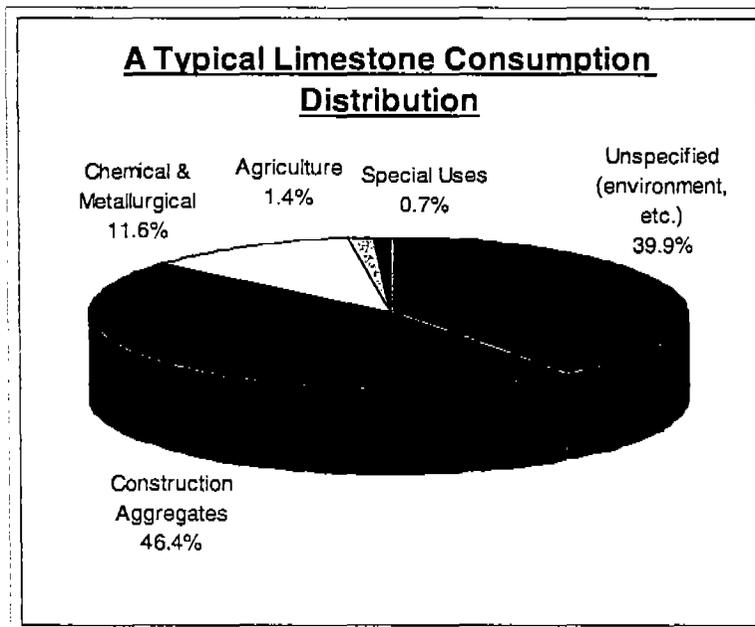
Limestone competes with many other natural materials including dolomite, dimensional stones, and other synthetic materials and due to the bulky nature of such materials, transport costs, and hence proximity of supply are the major factors which influence a customer's choice of material (application). However, there are certain physical and minor chemical aspects which have to be considered when assessing the suitability of a limestone for various uses. The major factors that influence the application of limestone are strength and hardness, cleanness, particle shape, chemical soundness, and color. A typical application of limestone is given below.



However, major application classifications of limestone in natural form or modified form, based on this volume of consumption, can be divided into the following categories:

- Aggregates and construction
- Agricultural
- Environmental
- Chemical and Industrial
- Metallurgical

A typical limestone consumption for various applications in the world is shown on the following page.



### 6.1.1 **Aggregates and Construction**

Limestone has to compete with many other cheaper materials for construction applications. Only harder limestone or marbleized material find wider application. The requirements for such materials are mainly physical characteristics and particle size distribution. As an aggregate, limestone is used as a road stone, cement aggregate, coarse and fine asphalt filler, railway ballast, and many other constructional applications from landfill and sea wall defenses to roofing granules and pebble dash.

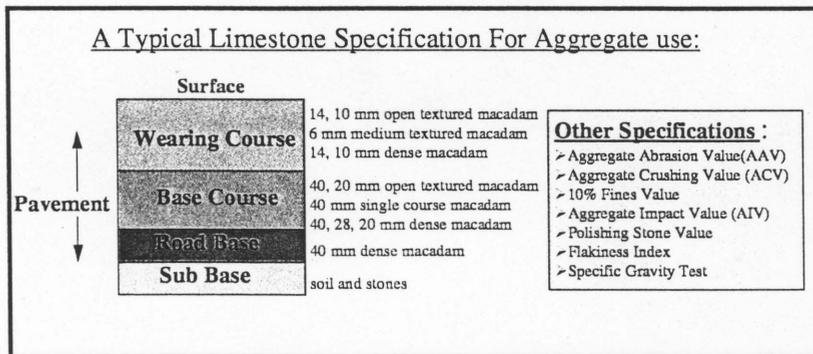
#### ➤ **Market**

The aggregate and construction markets are somewhat limited consumers of limestone due to availability and cost. Exact figures on tonnage consumed are unlikely to be resolved since large numbers of producers work both limestone and dolomite but do not distinguish between two materials.

**Road Pavement:** Crushed limestone is used extensively in construction of lower levels of the road. Major factors considered in the application are particle size distribution and porosity. The porosity of the material should be minimum to resist the effects of ice and water. The size distribution of single sized aggregates should be less than 50 mm but not less than 3 mm. The maximum permissible flakiness index is around 40% for single sized material and 35% for the finer material. Following is a typical specification for the limestone necessary for aggregate use.



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Tests mentioned in the block above are necessary to determine the suitability of the material for the application. Among the potentially deleterious substances that may occur naturally in some limestone are chert, clay, and shale. Although limestone is somewhat restricted in its use in the wearing course of the road pavement, it certainly finds a significant bulk market in the lower courses.

**Fillers In Asphaltic Compounds:** Coarse and fine materials of limestone are employed in the various hot and cold processes as asphalt employed in road coating. There are two types of applications: cold and hot asphalt. Cold asphalt requires a 10 mm nominal size with >95% minus 10 mm sieve or a 6 mm nominal size with >75% minus 2.36 mm sieve material. Hot process asphalt requires differing amounts of aggregate and fillers. For example, limestone rolled asphalt requires >85% minus 0.075 mm sieve material with bulk density of >0.5g/ml and not exceeding 0.9g/ml. Other coarser varieties of material are also used in hot asphalt depending on specific application and host country standards.

**Concrete:** Another significant market for the limestone aggregate is in the various forms of constructional concrete. The specifications for such use are dependent on the host country's National Standards for cement. In general this requires a dense hard material with low porosity to resist frost attack. The material must be free from any clay, mica, shale or other platy or laminated particles in addition to being free of any soluble sulfide or organic material. Amorphous silica, chloride ion content should be minimal (<0.06%). Typical properties required for limestone for concrete applications are given below.

A Typical Limestone Specification for Concrete:

Type of Concrete	10% Fine Value (not less than)	Aggregate Impact Value
Heavy Duty Concrete Floor Finishes	150 kN	25
Pavement Wearing Surfaces	100 kN	30
Others	50 kN	45
<b>Other Characteristics:</b>		
A Max 3% minus 0.075mm Fines A Max Flakiness Value of 35%		

**Railway Ballast:** Until now, limestone is benefited from a large market as a railway ballast material but recently many countries raised the physical requirement standards that may exclude limestone.

**HATCH**

**Marbles to Barrier:** This has limited applications. Hard limestone is used as decorative building stones. Large stone fragments are used as rip-rap for sea defenses, spillways for dams, and foundation support. However, the cost of transportation may determine its end use. Roofing granules and pebbledash applications are other markets in which limestone can participate. Its whiteness not only looks good but reflects the sun's rays thus acting as a heat insulator for the house. Average particle size required for this application varies from country to country (typical size is around 0.75 inches to 8 mesh).

### 6.1.2 Agriculture

Limestone has been used in agriculture long before man knew the real nature of how it benefited crop growth and soil fertility. Even today, limestone is used extensively in modern agriculture. For example, the UK government actively encouraged lime use by granting subsidies from 1939 which at times reduced nearly 75% of the cost of the material up until 1976. The main function of the limestone is to reduce soil acidity and supply calcium and magnesium nutrients to the soil. A typical specification for agriculture use is given below.

**A Typical Limestone Specification for  
Agriculture Application:**

- Consist Mainly CaCO<sub>3</sub>
- Magnesium Content Should Not Exceed 3%
- 100% Pass Through a 4.76mm Sieve
- At Least 96% Pass Through a 3.18mm Sieve
- At Least 40% Pass Through a 0.15mm Sieve

Natural limestone is also used as a calcium nutrient in animal and bird foodstuffs as additives in dry mash or pelleted formulation. There appears to be no formal specification in this application. The chemical purity and particle size distribution is being dictated largely by the feed compounding companies in association with the limestone suppliers. Typical requirements are as follows: calcium content should be as high as possible and there should be a minimal amount of magnesium oxide, silica, iron, alumina, and other toxic elements.

### 6.1.3 Environmental Applications

Every year world electric generating plants produce about 60 million tons of sulphur. The utilities burn more than 180 million tons of coal and 120 million tons of oil with an average sulphur content of 1.5% and 1.3% respectively. The resultant large emission of sulphur is precipitated out as acid rain. Hence, the Clean Air Act of 1970 sets the national standard for emission of SO<sub>2</sub> from utility plants at 1.2 pounds per million Btus to achieve a cleaner environment. The main system to remove or capture sulphur before escaping to the atmosphere is being universally identified as Fluid Gas Desulphurization (FGD).

Limestone is by far the most popular desulphurizing agent mainly due to its widespread availability, technical efficiency, and cost competitiveness. Wet scrubbing has been found to be more effective for high sulphur coals and so a limestone sludge is used as the absorbent. There are very few general specifications for limestone to use in FGD system. Main characteristics considered are fineness and chemical purity. A high grade limestone is required between 85-95% CaCO<sub>3</sub> with a maximum 5% acid insolubles. Small amounts of iron content may be beneficial but high magnesium content (>5%) is a problem. A typical limestone specification used for FGD operation is given below.



**HATCH**

**A Typical Specification of Limestone  
for FGD System**

- CaCO<sub>3</sub> Content Should be Between 85-90%
- Less Than 5% Acid Insolubles
- Less Than 5% MgO Content
- 84% Passing Through 325 mesh
- Higher Micro-porosity and Surface Area

➤ **Market Size**

Estimating the exact tonnage of limestone required for FGD units is particularly difficult because of the plethora of variables including plant capacity, sulphur content of the fuel, FGD efficiency, etc. A general attempt is made in the US by Illinois Geological Survey to estimate the lime and limestone requirements for FGD system (it is around 2.6 million tons of limestone for 1992 which is around one-third of the world requirement).

**6.1.4 Chemical and Industrial**

➤ **Filler and Extender**

Pure, fine grained, white limestone materials are generally covered by the common term "whitings". Although color and brightness are premium qualities in a whitener, the physical structure of the rock is an important factor in determining the ease of grindability, and therefore fineness that can be economically achieved. Due to the vast range of applications in the whiteners business grades tend to be of a more customized nature. However, only well established specifications exist for the application of paint extender, road paint filler, and putty applications. General characteristics necessary for the whiteners are as follows:

- Very good whiteness and high degree of reflectivity
- Particle size from 10 microns downwards
- A custom particle size distribution
- High specific surface area and shape
- Known plastic and rheological characteristics
- Particular absorption characteristics in regard to oils, inks and pigments
- A relatively inert chemical nature
- Extreme purity
- Particular specific gravity and bulk densities

The major markets for limestone whiting are most certainly in the paint, plastics, paper and floor covering applications although the ceramic, fertilizer, cream polish, insecticide, modeling clay, putties, and mastics industries certainly contribute to total sales. There are various specifications for limestone to be used in paint extender. A typical British specification from the literature is given below.



ISO 9001-84  
Registered

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**A Typical British Limestone Specification for Extender in Paint**

	No. 2 Extender	No. 3 Extender
<b>Chemical Specification:</b>		
% Ca-carbonate	96-99	98
Matter Volatile, 105 C	0.3%	0.3%
Loss On Ignition, %	42-44	42-44
Matter Soluble in Water, %	0.15	0.15
pH of aqueous Solution	8.0-9.5	8-10
<b>Physical Specification:</b>		
Particle size	< 10 microns Others(as per the requirements)	< 10 microns

There are two main areas of whiting used in the paper industry, one as paper filler used in conjunction with adhesives such as starch and resin to fill the interstices between the intermeshed cellulose fiber; and the other found in paper coating employing a finer material with high brightness. For paper filler, particle size is commonly 30-40% minus 2 microns with around 0-20% plus 10 microns. However, the paper coating industry requires a more sophisticated kind of product with extremely high brightness with very precise fineness. Material should contain 80-90% minus 2 microns with a brightness value approaching 90.

Whitings employed as fillers in rubber and plastics not only reduce the polymer raw material cost but also contribute to additional mechanical, chemical, and even electrical performance. Again, high purity limestone is needed for these applications as the concentration of copper, lead, and manganese can effect the polymer material itself as they tend to inhibit vulcanization and lead to bad aging properties (Cu < 0.005%, MnO < 0.02%, Pb<0.05% and Si<<0.5%). A typical limestone specification discussed in literature (for various uses) is given below.

**Typical Limestone Specifications For ECC Whitings**

Typical Applications	Paint	Rubber	PVC	Paper Filler	Paper Coating	Polish Chemicals
ECC Product Specification	Queensgate "Paris White"	Polcarb	G400	Queensfill	NP100	Carbital (marble) Queensgate 19
CaCO <sub>3</sub> , %	96.15	98.5	98.5	96.15	98.5	98.1
Water Solubles Salt, %	0.13	0.10	0.14	0.13	0.14	-
Moisture Content, %	0.20	20.0	1.0	15	-	-
Specific Surface, m <sup>2</sup> /g	2.7	6.0	1.88	2.2	8.0	5-16
Brightness, %	85.5	89-90	84	85.5	89.0	96.0
<b>Particle Size Distribution</b>						
+53 microns	0.3	0.02	0.1	0.75	0.02	0.01
+10 microns	18	1.0	13	18	1.0	1.0
+ 5 microns	33	2.5	35	35	2.5	4.0
- 2 microns	36	77-83	40	40	77-83	90
- 1 microns	-	42	-	-	42	70

Putties and mastic sealant require a large percentage input of whitings. Putties contain as much as 85-90% CaCO<sub>3</sub> and the remainder is linseed oil. Whitings used for these applications should have dense particle size distribution with low absorption properties so as to minimize the oil load in the media. A typical limestone used as linseed oil putty is given below.



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<u>A Typical Limestone Specification For Linseed Oil Putty</u>			
<u>Chemical</u>	CaCO <sub>3</sub>	>94%	
	Acid Soluble Matter	<4%	
	pH of aqueous Soln	8-10	
	Volatile Matter, 105C	0.25%	
<u>Physical</u>	<u>Size</u>	<u>% Undersize</u>	<u>% Residue</u>
	500	99.99min	0.01max
	125	99.0min	1.0max
	63	94.0min	6.0max
	45	84.0min	16.0max
	32	92.0max	--
	4	40-50	--

➤ **Coal Dust Blend**

A coarser grade limestone flour is required in the coal mining industry as a fire dampener employed to reduce the combustible nature of coal dust during blasting. The powdered limestone is spread among the mine galleries and roadways to form an intimate mixture with the coal dust so when the particles are thrown up during the hot blast of an explosion, the heat capacity properties of the coal are drastically reduced and combustion thwarted. A typical US and UK specification for limestone is given below.

<u>A Typical Limestone Specification For Coal Dust</u>	
<u>in US</u>	<u>in UK</u>
<u>Particle Size</u>	
100% -20 mesh	90% -0.250mm
70% -200 mesh	50-70% -0.063mm
<u>Silica Content</u>	
4% max	3% max
<u>Combustible Content</u>	
5% max	-
<u>Others</u>	
Light colored dust that when wetted does not cake on drying	Easy dispersion from air No caking Uniform color

Since limestone calcite crystals in whittings possess a Moh's hardness of 3, they exhibit a mild degree of abrasiveness which is fully utilized in the various cream polishes and scouring powders employed in home and industry.



**HATCH**

➤ **Glass Industry**

Limestone is the important component in glass manufacture because of its fluxing action on the silica sand to form a chemically fused calcium silicate glass phase. Apart from combining with silica raw material, CaO content of the limestone also improves the chemical and physical characteristics of the glass by increasing the strength and reduces brittleness, and also contributes to a more enduring luster to the appearance of the finished product. Although chemical and particle size distribution requirements are very important and should be compatible with other raw materials (silica), iron content slightly varies for different glass producing industries. The four major areas of glass industries are as follows with maximum tolerable iron content in the bracket: flat glass (0.05%), container glass (0.02-0.025%), fiber glass (0.035%), special glass -high-tech (0.0013 - 0.0026%). A typical specification of limestone for colorless glass is given below.

<u><b>A Typical Limestone Specification for Colorless Glass</b></u>		
<u><b>Chemical</b></u>	CaO	>55.2%
	CaCO <sub>3</sub>	>98.5%
	FeO	< 0.035%
	Acid Insoluble	<1.0%
	Organic Matter	<1.0%
	Moisture Content	<2.0%
	➤ Mn, Pb, & S values should be less than 0.1% (each)	
	➤ Coloring elements should be negligible	
	➤ Alumina and magnesia should be limited	

➤ **Cement**

The cement industry has traditionally used a wet cement process where at high temperature CaO components of the limestone fuse with the aluminosilicates to form a clinker at 1,600 C. This clinker is ground down with other minerals to enhance cement performance. However, now-a-days a semi-wet or dry method is followed to conserve energy. There is hardly any definite specification existing for the raw materials. Cement producers have to balance the chemical purity of the limestone material with the clay input to give a product recipe which meets the requirements of the cement specification. A typical limestone specification for Portland cement is given below.



**HATCH**

**A Typical Limestone Specification For  
Portland Cement**

<b>Lime Saturation Factor</b> (CaO-0.7SO3)/(2.8SiO2+1.2Al2O3+0.65Fe2O3)	<b>0.66-1.02</b>
<b>Acid Insoluble residue</b>	<b>&lt;1.5%</b>
<b>MgO content</b>	<b>&lt;4.0%</b>
<b>SO3 content</b>	<b>&lt;2.5-3%</b>
<b>Loss on ignition</b>	<b>3-4%</b>
<b>Fluorine</b>	<b>&lt;0.1%</b>
<b>Phosphates</b>	<b>&lt;0.5%</b>
<b>Minimum amount of alkaline metals, sulphur</b>	

➤ **Other Industrial Applications**

**Quicklime:** In many industrial processes it is the CaO molecule (lime) that promotes the chemical reaction. The lime producing process involves the calcination of limestone in various kiln configurations which usually employs preheater, kiln, and burning zone, and a cooler system. Lime applications are discussed later in the lime section as modified carbonates because lime is the generalized term used for all calcined material (both dolomite and limestone calcination product is called lime).

**6.1.5 Metallurgical**

Limestone has always been the major flux material for the metallurgical industries that produce slag, especially pig iron producing industries. Limestone was involved in the production of pig iron since before the Industrial Revolution. In the traditional pig iron process, the charge of iron ore, coke, and limestone is introduced to the blast furnace where the various chemical processes are enacted under the furnace heat. Limestone is calcined under the heat and the oxides of calcium and magnesium combine with the silica and alumina impurities from the ore to form the slag. The molten iron sinks to the bottom of the furnace with the slag, floating on the top, scavenges sulphur from the iron which is originally derived from the coke fuel.

Although iron plants all around the world differ in their particular operational recipes, the limestone specs are certainly on the fine side. One main characteristic is the requirement of hard limestone to limit the fines. The chemical purity is not particularly important but higher CaO content is advantageous. A typical specification is given below.

**Typical Limestone Specifications For  
Metallurgical Use**

<b>Particle size</b>	<b>100% -5mm</b> <b>95-96% -3mm</b> <b>&gt;90% 0.15mm</b>
➤ <b>Fines below 0.075mm are unacceptable</b>	
➤ <b>CaO content should be as high as possible</b>	
➤ <b>Si, S, P and others should be less than 1% each</b>	



## HATCH

### 6.1.6 Production and Market Overview

#### ➤ World

Exact figures on tonnage consumed are unlikely to be resolved since a large number of producers work both limestone and dolomite but do not distinguish between two materials. The world limestone output in 1997 was around 10,000 million tons with approximately 45% was "Unspecified, actual and estimated" uses. Of the remaining, 70% is used as construction aggregates; 25% for chemical and metallurgical uses including cement and lime manufacturing; 1.5% for agricultural uses; 1% for special uses and products.

#### ➤ Australia

Australian production of limestone remained constant over the years. In 1997, according to the Mineral Industry of Australia, produced around 12 million tons of limestone which is approximately the same as the produced amount in 1993. This amount excludes limestone used in road pavement applications. The majority of this limestone (around 6 million tons) has been used for cement manufacturing (excluding construction) applications and rest is mostly chemical and metallurgical uses. A very small amount of limestone is used in agriculture and specialty product applications. There are so many quarries that produce limestone it may not be possible to collect the list and reproduce them in this report and hence, is eliminated in the discussion. However, Australia imports large amounts of limestone and dolomite from Canada, UK, and China for various applications, especially in the metallurgical and lime manufacturing applications. The total volume may exceed 2 million tons. China has one of the largest reserves of dolomite and limestone and can supply chief material to the Australian market.

#### ➤ USA

The 1997 output of crushed limestone, including some dolomite, increased by 5.5% to 916 million tons valued at \$4.8 billion compared with the revised 1996 total. In addition to the quarries reporting only limestone, 65 operations with 68 quarries reported producing limestone and dolomite without making a distinction between the two kinds of stone. Their combined production, 31.1 million tons, was included with the limestone. The limestone totals shown in this chapter, therefore, include an undetermined amount of dolomite in addition to the dolomite reported separately. Limestone was produced by 819 companies at 1,835 operations with 1,990 quarries in 48 States. In addition, 47 companies with 65 operations and 68 quarries reported producing limestone and dolomite from the same quarries. The leading producing States were, in descending order of tonnage, Texas, Florida, Missouri, Kentucky, and Illinois; these five states accounted for 36.4% of the total USA output. The leading producers were, in descending order of tonnage, Vulcan Materials Co., Martin Marietta Aggregates, Cornerstone Construction & Materials, Inc., CSR America, Inc., and Rogers Group, Inc.

Of the 916 million tons of crushed limestone consumed, 375 million tons or 41% was "Unspecified, actual and estimated" uses. Of the remaining 540 million tons of crushed limestone reported by uses, 76.5%, was used as construction aggregates; 20.3% for chemical and metallurgical uses including cement and lime manufacturing; 2% for agricultural uses; 1.1% for special uses and products. Distribution of limestone production for various use is given in the following table. The price per ton for individual applications can be calculated by dividing value in US\$ with quantity (tons) (the prices are approximate and f.o.b.).



**HATCH**

**CRUSHED LIMESTONE SOLD OR USED BY PRODUCERS IN THE  
UNITED STATES IN 1997, BY USE 1/ 2/  
(Thousand metric tons and thousand dollars)**

Use	Quantity	Value, US\$
Coarse Aggregate (+1 1/2 inch)		
Macadam	2,950	15,700
Riprap and jetty stone	14,500	66,900
Filter stone	4,130	22,300
Other coarse aggregate	8,720	42,500
Coarse aggregate, graded:		
Concrete aggregate, coarse	56,500	298,000
Bituminous aggregate, coarse	49,400	290,000
Bituminous aggregate, fine	10,200	55,400
Railroad ballast	2,920	15,800
Other graded coarse aggregate	28,300	188,000
Fine aggregate (-3/8 inch):		
Stone sand, concrete	10,100	50,100
Stone sand, bituminous mix or seal	12,500	66,700
Screening, undesignated	18,400	68,200
Other fine aggregate	5,880	33,000
Coarse and fine aggregate:		
Graded road base or subbase	107,000	473,000
Unpaved road surfacing	19,000	94,100
Terrazzo and exposed aggregates	412	2,760
Crusher run or fill or waste	35,900	163,000
Other coarse and fine aggregate	20,800	114,000
Roofing granules	228	1,930
Other construction materials	5,340 3/	27,700 3/
Agricultural:		
Agricultural limestone	9,750	54,800
Poultry grit and mineral food	745	9,120
Other agricultural uses	547	3,680
Chemical and metallurgical:		
Cement manufacture	83,000	300,000
Lime manufacture	19,100	97,700
Dead-burned dolomite manufacture	W	W
Flux stone	5,320	24,400
Chemical stone	190	1,010
Glass manufacture	W	W
Sulfur oxide removal	1,910	11,400
Special:		
Mine dusting or acid water treatment	256	4,230
Asphalt fillers or extenders	848	7,780
Whiting or whiting substitute	1,930	63,800
Other fillers or extenders	1,850	28,300
Other specified uses not listed	1,260	8,040
Unspecified: 4/		
Actual	245,000	1,380,000
Estimated	131,000	699,000
<b>Total</b>	<b>916,000</b>	<b>4,780,000</b>

W - Withheld to avoid disclosing company proprietary data; included with "Other specified uses not listed."

1/ Includes a minor amount of limestone-dolomite reported without a distinction between the two.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes building products, drain fields, pipe bedding, and waste material.

4/ Includes production reported without a breakdown by end use and estimates for non-respondents.



**HATCH**

➤ Price

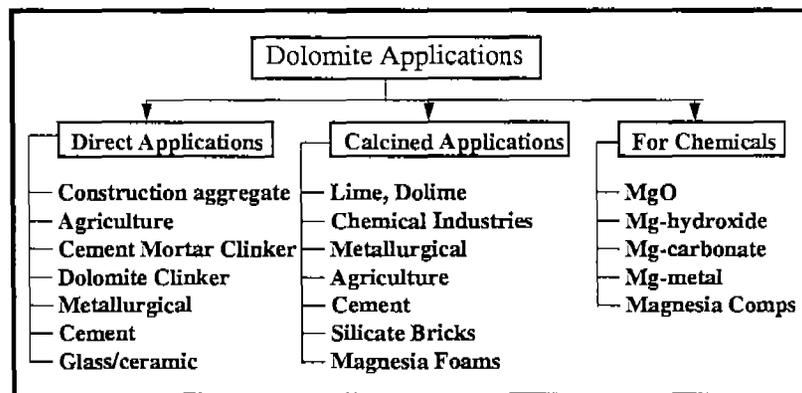
Prices in this chapter are f.o.b. plant, usually at the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, in-plant transportation, overhead costs, and profit. The average unit price per ton of limestone increased by 4.8% to \$5.66, compared with that of 1996.

➤ Exports and Imports

The widespread distribution of limestone and dolomite and high cost of transportation limits foreign trade to mostly local transactions across international boundaries. US import and exports are small, representing less than 1% of the domestic consumption. Shipments of crushed stone by water from Canada and especially Mexico, however, continue to increase. In 1997, about 4.0 million tons, worth \$42 million, of limestone is exported with Canada being the major destination with 78.3% of it, followed by Japan with 4.7%. Imports of crushed stone increased by 10% in 1997 over 1996 to 12.4 million tons, worth around \$106 million. The import is mainly from Canada, Mexico, and Bahamas. This is mostly used as construction aggregates or for cement manufacturing.

**6.2 Dolomite**

The most important uses of dolomite are in the manufacture of magnesia refractories, high magnesia lime, special cements, a flux for ferroalloys, and as a source for magnesium. There are many other applications which are categorized below. In general, dolomite application can be divided on the basis of its physical form or based on end uses. A general application of dolomite is given below.



The physical form uses of dolomite can be classified as follows:

- Direct Applications
- Uses of Selectively Calcined Dolomite
- Chemicals from Dolomite

However it is much easier to categorize them on the basis of end uses. The triangle diagram discussed earlier in the classification section shows the classification based on end-use chemical composition and mineralogy. They are:

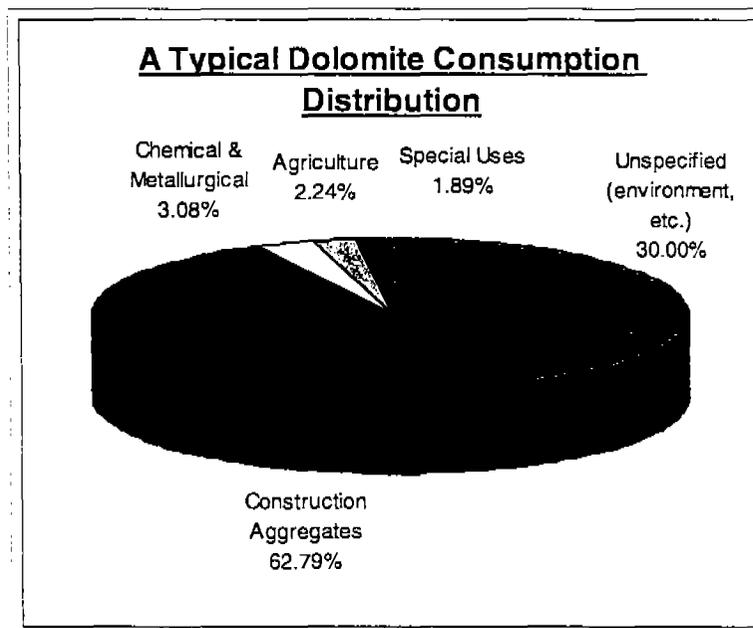


**HATCH**

- Aggregates and Construction
- Chemical and Metallurgical
- Agriculture
- Miscellaneous Categories

These groups are also approximate order of magnitude by consumption. Most of the applications demand dolomite in the form of crushed, dried stone to particular size ranges although some uses, which are more specialized, require burnt and/or treated dolomite products of particular composition. For all dolomite products there exist specifications to be met for desired end performance characteristics. These specifications are usually drawn up either by industry, government bodies or active national organizations (ASST., BSI, etc.). Some of these end markets for dolomite have witnessed changing raw material requirements/specifications over the years, usually becoming increasingly stringent and economic, while others have experienced little or no change. Let us look into the applications of dolomite in this section based more on direct applications and less on its modified form.

A typical dolomite application/consumption distribution in the world is given below.



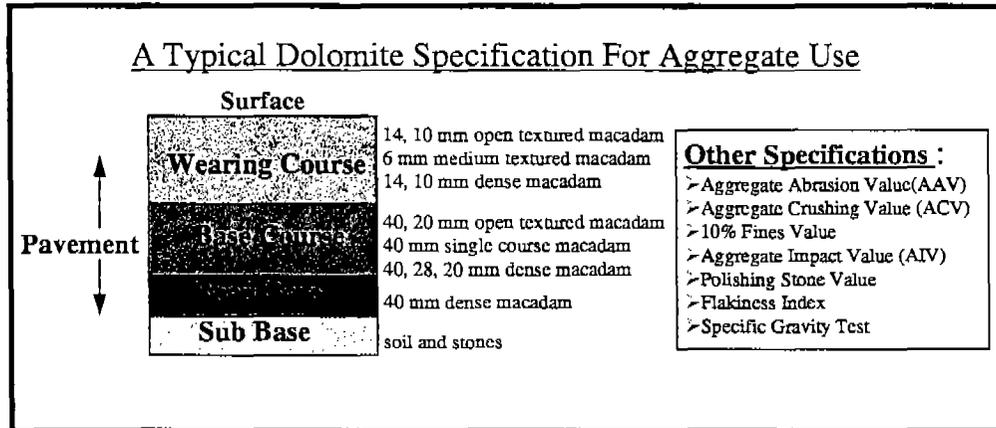
**6.2.1 Aggregates and Construction**

Crushed dolomite is used in Portland cement, concrete roads, buildings, and other structures and in combination with bituminous materials for roads and similar construction. Dolomite is also used to make base courses for various types of pavements, to make water-bound macadam and soil aggregate roads. The requirements for materials for road aggregates are mainly physical characteristics and particle size distribution. As an aggregate, dolomite is used as a road stone, cement aggregate, coarse and fine asphalt filler, railway ballast, and many other constructional applications from landfill and sea wall defenses to roofing granules and pebble dash. The aggregate and construction market is the single largest consumer of dolomite. Exact figures on tonnage consumed are unlikely to be resolved since a large number of producers work both limestone and dolomite but do not distinguish between two materials.



**HATCH**

**Road Pavement:** Crushed dolomite is used extensively in construction of all levels of the roads, especially lower levels of the road. Major factors considered in the application are particle size distribution and porosity. The porosity of the material should be minimum to resist the effects of ice and water. The size distribution of single sized aggregates should be less than 50 mm but not less than 3 mm. The maximum permissible flakiness index is around 40% for single sized material and 35% for the finer material. Following is a typical specification for the dolomite for road pavement aggregate application which is similar to that of limestone.



The tests mentioned in the block above are necessary to predict whether a dolomite is suitable as an aggregate raw material. However, it is generally regarded that dolomites which are light in weight or which have a high porosity or water absorption should be regarded with suspicion. Impure dolomite, especially clayey, dull appearing dolomites are likely to fail in the tests as are those which break readily when struck with a hammer. Among the potential deleterious materials that may occur naturally in some dolomites, excluding overburden or quarry floor materials are cherts, shalem, and clay. A typical tolerable amount of clay lumps is around 1% in fine aggregates and 0.25% in coarse aggregates. Others such as cherts and shale should not exceed 5% in the material for application. Presence of opaque silica, alkalis, and organic matters are highly undesirable.

**Asphalt Filler:** Asphalt filler material is also provided for by finely powdered dolomite. Coarse and fine materials are also found in the various hot and cold process asphalt employed in road coating. There are two types of applications similar to that of limestone - cold and hot asphalt. However, soluble matters and chemical compositions may be the limiting factors in application. Cold asphalt requires a 10 mm nominal size with >95% minus 10 mm sieve or a 6 mm nominal size with >75% minus 2.36 mm sieve material. Hot process asphalt requires differing amounts of aggregate and fillers. For example, limestone rolled asphalt requires >85% minus 0.075 mm sieve material with bulk density of >0.5g/ml and not exceeding 0.9g/ml. Other coarser variety material is also used in hot asphalt depending on specific applications and host country standards. Bituminous concrete pavement requires 100% material passing a number 30 sieve and a total of not less than 65% passing through a number 200 sieve.

**Concrete:** Another significant market for the dolomite aggregate is in the various forms of constructional concrete. The specifications for such use are contained within the host country's National Standards for cement. This application requires a dense hard material with low porosity to resist frost attack. The material must be free from any clay, mica, shale or other platy or laminated particles in addition to being free of any soluble sulfide or organic material. Amorphous silica, chloride ion content should be minimal (<0.06%). Following is a typical dolomite requirement for concrete.



**HATCH**

<u>A Typical Dolomite Specification for Concrete</u>		
Type of Concrete	10% Fine Value (not less than)	Aggregate Impact Value
Heavy Duty Concrete Floor Finishes	150 kN	25
Pavement Wearing Surfaces	100 kN	30
Others	50 kN	45
<b>Other Characteristics:</b> A Max 3% minus 0.075mm Fines A Max Flakiness Value of 35%		

**Railway Ballast:** Until now, dolomite is benefited from a large market as a railway ballast material but recently many countries raised the physical requirement standards that may exclude limestone and dolomite.

### 6.2.2 Agriculture

This market commonly represents dolomite's second largest consumer. Dolomite products for this market come under the all-embracing term aglime, which is synonymous with agstone. Aglime is produced by crushing and grinding dolomitic limestone or calcitic dolomite to a gradation or fitness that will enable it to neutralize soil acidity, usually to pass sieves in the 8-100 mesh range or finer.

Dolomite (aglime) neutralizes soil acidity through base exchange, with the calcium and magnesium cations displacing the hydrogen ions in the soil. According to a publication report, this process results in a 15-40% increase in crop yield. The optimum grain size is 1.25 - 0.18 microns as a free flowing powder. A typical practice is to add 4.0 lb of dolomite to 2.15 lb of urea to counter the acidity generated from urea. There are encouraging signs that consumers of aglime are beginning to appreciate its benefits. A typical property requirement for dolomite for the agriculture application is given below.

<u>A Typical Dolomite Specification for Agriculture Use</u>	
Optimum Grain Size	1.25 - 0.18 microns
Powder Type	Free Flowing Powder
Chemical Purity	Depending on Consumer and Type of Blend



## HATCH

### ➤ Other Agriculture Uses

Other agriculture applications include dolomite's use as "barn stone", where it is sprinkled on the floors and walls of stock barns, especially dairy barns, to serve as a neutralizing agent and absorbent of organic wastes and also to give a clean appearance. In fertilizers, dolomite may be used as a filler material to add weight, reduce caking, and improve physical condition of the mixture, and also to adjust the blend to the desired ratios of fertilizing elements. Dolomite also neutralizes the physiological acidity of the fertilizer. Dolomite finds some use as poultry grit and mineral food.

### 6.2.3 Chemical and Industrial

#### ➤ Lime - Dolime, Doloma

Lime (also called burnt lime) refers to the end product of calcining dolomite and is chiefly composed of CaO and MgO in quantities proportional to the original carbonate content of the source rock. Dolime may contain 18-45% MgO and 30-57.5% CaO depending on the raw material burnt, and can also be referred to as low or high magnesia lime.

There are other forms of burnt dolomite used in the industry known as hard or dead burnt dolomite, refractory lime or doloma. This material is formed from sintering or dead burning at high temperature to produce more denser and more inert product. Details of the calcination process and its applications are discussed later in the section.

#### ➤ Filler and Extender

Pure, fine grained white dolomite, especially calcitic dolomite or dolomitic limestone materials, are generally covered by the common term "whitings". Although color and brightness are premium qualities in a whitener, the physical structure of the rock is an important factor in determining the ease of grindability and therefore fineness that can be economically achieved. Due to the vast range of applications in the whiteners, business grades tend to be of a more customized nature. However, only well established specifications exist for the application of road paint filler and putty applications. General characteristics necessary for the whiteners are as follows.

#### Typical (Dolomite or Limestone) General Characteristics for Whiteners

- Very good whiteness and high degree of reflectivity
- Particle size from 10 microns downwards
- A custom particle size distribution
- High specific surface area and shape
- Known plastic and rheological characteristics
- Particular absorption characteristics in regard to oil, inks and pigments
- A relatively inert chemical nature
- An extreme purity
- Controlled specific gravity and bulk densities



**HATCH**

The major markets for dolomitic limestone whitening are most certainly in the paint, plastics, paper, and floor covering applications although the ceramic, fertilizer, cream polish, insecticide, modeling clay, putties, and mastics industries certainly contribute to total sales.

Since dolomite calcite crystals in whittings possess a Moh's hardness of 3, they exhibit a mild degree of abrasiveness which is fully utilized in the various cream polishes and scouring powders employed in home and industry.

➤ **Coal Dust Blend**

A coarser grade dolomite or dolomitic limestone flour is required in the coal mining industry as a fire dampener employed to reduce the combustible nature of coal dust during blasting. The powdered dolomitic material is spread among the mine galleries and roadways to form an intimate mixture with the coal dust so when the particles are thrown up during the hot blast of an explosion, the heat capacity properties of the coal are drastically reduced and combustion thwarted. A typical US and UK specification for dolomite needed for a coal dust blend application is given below.

<u>A Typical Dolomite Specification For Coal Dust</u>	
<u>in US</u>	<u>in UK</u>
<b><u>Particle Size</u></b>	
100% -20 mesh	90% -0.250mm
70% -200 mesh	50-70% -0.063mm
<b><u>Silica Content</u></b>	
4% max	3% max
<b><u>Combustible Content</u></b>	
5% max	-
<b><u>Others</u></b>	
Light colored dust that when wetted does not cake on drying	Easy dispersion from air No caking Uniform color

➤ **Glass Industry**

After silica sand and soda ash, limestone and dolomite are the third largest constituents of the glass batch. The carbonate rock's prime function is in the introduction of CaO as a major fluxing material into soda-lime-silica batches. Although dolomite also acts as a flux, it is rarely used in total substitution for limestone. Apart from combining with silica raw material, CaO content of the limestone also improves the chemical and physical characteristics of the glass by increasing the strength and reduces brittleness, and also contributes to a more enduring luster to the appearance of the finished product. There are two additional advantages with dolomite over limestone. Firstly, because magnesium ion weighs less than calcium ions, the alkaline earth contents of the glass can be easily achieved by using less material so weight for weight, dolomite is more attractive. Secondly, dolomite is more stable than limestone and not so reactive, thus facilitating easier handling.



**HATCH**

The chemical and particle size distribution requirements are very important to glass application and should be compatible with other raw materials (silica). The iron content requirements slightly vary for different glass producing industries so the main controlling factor in the application is the iron content of the dolomite. Dolomite main applications are in float glass and container glass. General specifications are similar to that of limestone used in the glass industry given earlier. A typical specification is given below.

<u>Typical Dolomite for Glass Applications:</u>			
<u>Chemical</u>	CaO	~ 57 %	
	MgO	~ 40 %	
	FeO	< 0.04 %	
	Fe <sub>2</sub> O <sub>3</sub>	< 0.4 %	
	Acid Insoluble (including silica)	< 1.0 %	
	Organic Matter	< 1.0 %	
	Moisture Content	< 2.0 %	
	Mn, Pb, P, S, etc.	< 0.1 % each	
	<u>Physical</u>	Example Spec 1	100 % minus 4.76 mm    75 % plus 0.124 mm
		Example Spec 2	100 % minus 3.175 mm    95 % plus 1.20 mm

➤ **Cement**

In common cement applications use of dolomite is rather limited. Semi-calcined dolomite can be employed to manufacture magnesium oxy-chloride and magnesium oxy-sulphate cement which is discussed in the calcined material section. The cement industry has traditionally used the wet cement process where at high temperature CaO and MgO components of the limestone fuses with the aluminosilicates to form a clinker at 1,600 C. This clinker is ground down with other minerals to enhance cement performance. However, now-a-days a semi-wet or dry method is followed to conserve energy. There is hardly any definite specification that exists for the raw materials. Cement producers have to balance the chemical purity of the limestone material with the clay input to give a product recipe which meets the requirements of the cement specification. A typical dolomite needed for cement applications is given below.

<u>A Typical Dolomite Specification For Portland Cement</u>	
<b>Lime Saturation Factor</b> <small>(CaO-0.7SO<sub>3</sub>)/(2.8SiO<sub>2</sub>+1.2Al<sub>2</sub>O<sub>3</sub>+0.65Fe<sub>2</sub>O<sub>3</sub>)</small>	<b>0.66-1.02</b>
<b>Acid Insoluble residue</b>	<b>&lt;1.5 %</b>
<b>MgO content</b>	<b>&lt;4.0 %</b>
<b>SO<sub>3</sub> content</b>	<b>&lt;2.5-3 %</b>
<b>Loss on ignition</b>	<b>3-4 %</b>
<b>Fluorine</b>	<b>&lt;0.1 %</b>
<b>Phosphates</b>	<b>&lt;0.5 %</b>
➤ <b>Minimum amount of alkaline metals, sulphur</b>	



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➤ **Cement Mortar**

In certain cases, adding up to 40% dolomite by weight to cement has been found to accelerate the rate of cement hydration. Experimental work involved the fine grinding of dolomite to obtain a surface area between 1-10 cm<sup>2</sup>/gm. This fine material is added to cement. The resultant material produced similar properties as that with limestone.

➤ **Treatment of Cracks**

The total weight of dolomite is 85% by weight of the total composition for material used for the treatment of cracks. At least 95% of the material should pass through a 150 micron sieve and at least 50% by weight passed a 53 micron sieve. Average particle size is at least 20 microns. Reminder - 15% is the aqueous resin binder emulsion.

➤ **Other Industrial Applications**

In addition to the above applications dolomite is known to be used in a host of smaller applications. These include filler applications in adhesives and sealant, paper, plastic, paints, putty rubber, plasters, carpet foam detergents, foods, and cosmetics amongst others. In these applications dolomite is finely ground to precise specifications. Dolomite fillers can also provide very cost effective substitutes for dearer TiO<sub>2</sub> levels in white/pastel formulations.

Dolomite rock can also be used as a sewage filter bed if it is durable, highly porous, and possesses an irregular surface to trap bacteria.

Other uses include mineral wool manufacture, flue gas desulphurization, dimension stone, and all kinds of applications as stone chips.

**6.2.4 Metallurgical**

Dolomite is used as a flux in steelmaking where it reacts with impurities in the melt such as silica, alumina, sulphur, and phosphorous to form a slag which can be separated from the metal. Generally speaking, there has been a worldwide move to produce higher quality steels to satisfy stringent customer specifications which may be bad news for dolomite. This has translated into tighter controls on raw material chemistry and consumption. However, there is good news for dolomite recently. Initially only a reactive high calcium lime was used in the industry, but later it was recognized that pure dolomite lime substituted for a portion of the high calcium flux resulted in greater refractory life. Specifications for the use of dolomite as a flux vary with the steelmaking process, kind of ore processed, and final use of the slag. A typical specification which is identical to that of limestone is given below.

<u>A Typical Dolomite Specification For</u>	
<u>Metallurgical Use</u>	
<u>Particle size</u>	100% -5mm
	95-96% -3mm
	>90% 0.15mm
➤ Fines below 0.075mm are unacceptable	
➤ CaO content should be as high as possible	
➤ Si, S, P and others should be less than 1% each	

**HATCH****6.2.5 Chemicals from Dolomite**

Dolomite is one of the primary raw materials for the manufacture of magnesium metal and some of its compounds.

In production of magnesium metal there are essentially two processes: electrolytic and the thermal reduction of magnesium oxide. Those companies employing dolomite are nearly always situated on or near deposits of dolomite. It is estimated that for pyrometallurgical process approximately 10 tonnes of dolomite are required to make one tonne of magnesium metal.

**Magnesium Metal Production Processes**

- **Dow process:** Magnesium hydroxide is precipitated from sea water by slurring with calcined dolomite and then converted to  $MgCl_2$  by reacting it with HCl. The dried granulated  $MgCl_2$  is then fused with alkali chlorides in electrolysis cells. Used by Dow Chemical Co, USA.
- **IG Farben Process:** Dolomite is used to precipitate  $Mg(OH)_2$  from sea water. The solid is filtered, calcined to the oxide, and pelletized with coke and  $MgCl_2$  brines. The resultant pellets are heated and electrolyzed. Used in USSR.
- **Norsk Process:** New process developed in Norway.  $Mg(OH)_2$  is precipitated from calcined dolomite and sea water and then burned to produce caustic calcined magnesia. This is mixed with the  $MgCl_2$  brines and carbon and then chlorinated to yield a fused anhydrous  $MgCl_2$ , a feed for a electrolytic cell. Used in Norsk Hydro, Norway.
- **Pidgeon Process:** Dolomite and ferrosilicon are briquetted and retorted in a small diameter vacuum furnace at 1100 C, forming a Ca-silicate slag and magnesium vapor which condenses and is recovered. Used by Ube industries, Furukawa magnesium co. Ltd in Japan, Chromasco Div., Timminco of Haley, Canada.
- **Italian Process:** Briquettes of dolomite and ferrosilicon heated in an electrically larger electric vacuum furnace and Mg vapor is condensed externally. Used by SAMI, Italy; Brasmag, Brazil.
- **Magnetherm Process:** Pelletized dolomite with pelletized alumina flux and ferrosilicon are heated together. Magnesium vapor condenses externally and is remelted under flux. Used by Pichiney Ellectrometallurgie, France; Northwest Alloys, USA; Magnohrom, Yugoslavia, Japan Metals & Chemicals, Japan.

Both magnesia and magnesium hydroxides are also manufactured through the use of dolomite. One of the major routes for magnesia is through the sea water/brines process. Magnesium hydroxide is also produced from brines through dolomite.

**6.2.6 Production and Market Overview****➤ World**

The aggregate and construction market is the single largest consumer of dolomite. Exact figures on tonnage consumed are unlikely to be resolved since a large number of producers work both limestone and dolomite but do not distinguish between two materials. The world dolomite output in 1997 was around 11,500 million tons, approximately 35% was "Unspecified,



**HATCH**

actual and estimated" uses. Of the remaining, 85% was used as construction aggregates; 5% for chemical and metallurgical uses; 2.5% for agricultural uses; and the rest for special uses and products.

**➤ Australia**

Australian production of dolomite remained constant over the years. In 1997, according to the Mineral Industry of Australia, produced around 10 million tons of dolomite which is approximately the same as the produced amount in 1993. The majority of this dolomite has followed the world distribution pattern. There are so many quarries that produce dolomite it may not be possible to collect the list and reproduce them here and hence, eliminated in the discussion. However, Australia imports large amounts of dolomite, limestone, and dolomitic limestone from Canada, UK, and China for various applications, especially in the metallurgical and lime manufacturing applications. The total volume may exceed 2 million tons. One fine example is Scotia Limestone Limited, Nova Scotia, Canada. Scotia Limestone owns a dolomite quarry at Kelly Cove on Cape Breton Island which contains estimated reserves of some 3.5 million tons and supplies demands of the steel plant at Sydney. China has one of the largest reserves of dolomite and limestone and can supply chief material to the Australian market.

**➤ USA**

Production of dolomite decreased by 8.5% to 98 million tons valued at \$547 million, compared with the revised 1996 total. Crushed dolomite was reportedly produced by 106 companies at 177 operations with 192 quarries in 26 States. An additional undetermined amount of dolomite is included in the total crushed limestone. The leading producing states were, in descending order of tonnage, Ohio, Pennsylvania, New York, Illinois, and Michigan. These five states accounted for 55.5% of the total US output. The leading producers were Oldcastle Inc., Cornerstone Construction & Materials, Inc., S.E. Johnson Co., ASARCO Incorporated/American Limestone Co., and Bardon Group, Inc.

Of the 98.2 million tons of crushed dolomite consumed, 34.8 million tons or 35.5%, was "Unspecified, actual and estimated" uses. Of the remaining 63.4 million tons of crushed dolomite reported by use, 91% was used as construction aggregates; 4.3% for chemical and metallurgical uses; 3.2% for agricultural uses; and 1.5% for special and miscellaneous uses. An additional undefined amount of dolomite consumed in a variety of uses, mostly construction aggregates, is reported with the limestone. Distribution of crushed dolomite in the US in 1997 is given in the following table. The approximate price per ton for individual use can be calculated by dividing value, US\$ with tonnage (the prices are approximate).

**CRUSHED DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN  
1997, BY USE 1/ 2/  
(Thousand metric tons and thousand dollars)**

Use	Quantity	Value, US\$
Coarse aggregate (+1 1/2 inch):		
Macadam 211 1,280		
Riprap and jetty stone	832	5,900
Filter stone	89	575
Other coarse aggregate	937	5,060
Coarse aggregate, graded:		
Concrete aggregate, coarse	7,800	41,100
Bituminous aggregate, coarse	7,120	51,500
Bituminous aggregate, fine	1,950	12,000



**HATCH**

**CRUSHED DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN  
1997, BY USE 1/ 2/  
(Thousand metric tons and thousand dollars)**

Use	Quantity	Value, US\$
Railroad ballast	895	5,230
Other graded coarse aggregate	3,840	23,000
Fine aggregate (-3/8 inch):		
Stone sand, concrete	1,050	6,370
Stone sand, bituminous mix or seal	1,290	9,700
Screening, undesignated	1,570	9,780
Other fine aggregate	516	2,520
Coarse and fine aggregate:		
Graded road base or subbase	10,500	52,000
Unpaved road surfacing	6,850	32,200
Terrazzo and exposed aggregates	W	W
Crusher run or fill or waste	1,960	9,690
Other coarse and fine aggregate	10,200	58,100
Roofing granules -- --		
Other construction materials 3/	111	620
Agricultural:		
Agricultural limestone	1,930	11,000
Poultry grit and mineral food	W	W
Other agricultural uses	82	864
Chemical and metallurgical:		
Cement manufacture	53	58
Lime manufacture	1,220	5,870
Dead-burned dolomite manufacture	W	W
Flux stone	1,430	6,420
Chemical stone	--	--
Glass manufacture	--	--
Sulfur oxide removal	--	--
Special:		
Mine dusting or acid water treatment	W	W
Asphalt fillers or extenders	W	W
Whiting or whiting substitute	--	--
Other fillers or extenders	497	11,100
Other specified uses not listed	461	3,550
Unspecified: 4/		
Actual	24,300	115,000
Estimated	10,500	66,800
<b>Total</b>	<b>98,200</b>	<b>547,000</b>

W - Withheld to avoid disclosing company proprietary data; included with "Other specified uses not listed."

1/ Includes a minor amount of limestone-dolomite reported without a distinction between the two.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ Includes building products, drain fields, pipe bedding, and waste material.

4/ Includes production reported without a breakdown by end use and estimates for non-respondents.

The global market for the refractory dolomite is now supplied by just six companies, five of which are headquartered in Europe. Total world production of this group is around 2 million tonnes per annum dead burnt dolomite. The companies are Baker Refractories USA; Lhoist Group, Belgium; Laradus Vermögensverwaltung GmbH, Germany; Lafarge SA, France; Veitsch Radex AG, Austria; and Carneuse, Belgium.

**HATCH****► Price**

Prices in this chapter are f.o.b. plant, usually at the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, in-plant transportation, overhead costs, and profit. The average unit price per ton of crushed stone increased by 4.8% to \$5.66 in 1997, compared with that of 1996.

**► Outlook**

The demand for crushed stone in 1998 is expected to be about 1.5 billion tons, a 5% increase over that of 1997. Gradual increases in demand for construction aggregates are anticipated after 1998 as well on the basis of the volume of work on the infrastructure that will be financed by the new Transportation Equity Act for the 21st Century, and the US economy in general. The projected increases will be influenced by construction activity in the public as well as the private construction sectors. Crushed stone f.o.b. prices are not expected to increase significantly. The delivered prices of crushed stone are, however, expected to increase, especially in and near metropolitan areas mainly because more aggregates are transported from distant sources.

**6.3 Burnt Carbonates - Lime/Dolime**

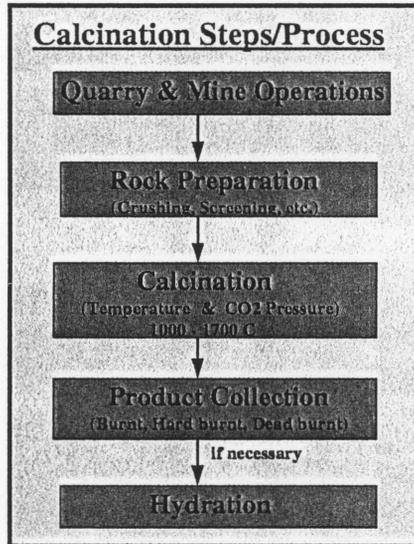
Lime is an important chemical with numerous chemical, industrial, and environmental uses in the United States. Its history probably dates back 4,000 to 6,000 years. The ancient Egyptians used lime as an ingredient in mortar and plaster. The Greeks, Romans, and Chinese used lime for construction, agriculture, bleaching, and tanning. Its uses began expanding with the advent of the industrial revolution, but it remained primarily a construction commodity until the rapid growth of the chemical process industries at the beginning of the 20th Century. At the turn of the century, over 80% of lime consumed in the United States went for construction uses, but now over 90% of lime is consumed for chemical and industrial uses. Lime's major uses were in steelmaking, flue gas desulphurization (FGD), pulp and paper manufacturing, construction, water purification, and ore concentration in the mining industry.

Total lime sold or used by US domestic producers in 1997, excluding that from Puerto Rico, increased by about 481,000 metric tons (530,000 short tons) to 19.7 million tons (21.7 million short tons) compared with the revised 1996 figures. Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. These products were valued at \$1.19 billion. Commercial sales increased by 494,000 tons (545,000 short tons) to a record high of 17.3 million tons (nearly 19.1 million short tons), and captive consumption decreased slightly to about 2.42 million tons (2.66 million short tons).

The term lime has been used to describe a wide variety of forms of calcareous materials, but here it is taken solely to mean burnt limestone or dolomite. Different types of lime arise from their chemical composition, nature of manufacture (e.g. degree of burning), and end use.

**6.3.1 Processing Lime**

Lime is usually made from limestone or dolomite or a combination of these two in various forms, generally having a minimum of 97% combined carbonate content with high calcium lines containing less than 55% MgO. When the lime is produced from dolomitic rock, the product is referred to as dolomitic lime or dolime. Production of lime involves three main processes: rock preparation, calcination, and, if required by end use, hydration. Typical steps are given below in the form of a block diagram.



Following are the critical variables in limestone/dolomite burning to generate lime:

- Stone quality - physical, decrepitation, impurities.
- Stone size and gradation.
- Rate of calcination.
- Calcination temperature and duration.
- Chemical reactivity.
- Shrinkage characteristics.
- Surface area and spacing of crystallites.
- Quality and type off fuel used.
- Possibility of recarbonation.
- Kiln type (fuel, cost, environmental aspect, market, etc.).

There have been numerous and varied calcination models developed for the reaction and it has been determined that calcination is a function of both temperature and CO<sub>2</sub> pressure. Calcination is strongly time variant with different sources of rocks. There are four types of calcination rocks:

1. Those that fracture and decrepitate readily during preheating and at low calcination temperature.
2. Those that yield a porous, reactive lime under most calcination conditions and that are difficult to overburn.
3. Those that yield a dense, unreactive lime of low porosity even under mildest calcining conditions.



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4. Those that yield a porous, reactive lime under mild temperature conditions and a denser, less porous lime under harder burning conditions.

Of these categories, 1 and 3 are rather undesirable, while for all around versatility, 4 in preference to 2 is most desirable. This is because adjustments can be made by a skillful operator in time-temperature conditions to manufacture a tailor made lime to suit a variety of purposes. Preference for a dry lime or hydrated lime depends largely on the volume of intended consumption and the type of storage and handling facilities.

The major impurities in lime may be silica, iron, alumina, and sulphur, and these range in importance depending on the lime end use. The type of lime also dictates its hydration characteristics. Dolomite lime is three order of magnitude slower reacting than that of pure calcium oxide. Early in the reaction, dolomite appears to be inert but given sufficient time it will hydrate. The time necessary to complete hydration may be in minutes if not hours for dolomite lime, whereas for CaO it is only seconds. A typical analysis of commercial burnt lime product is given below.

**Typical Specification for Commercial Lime**

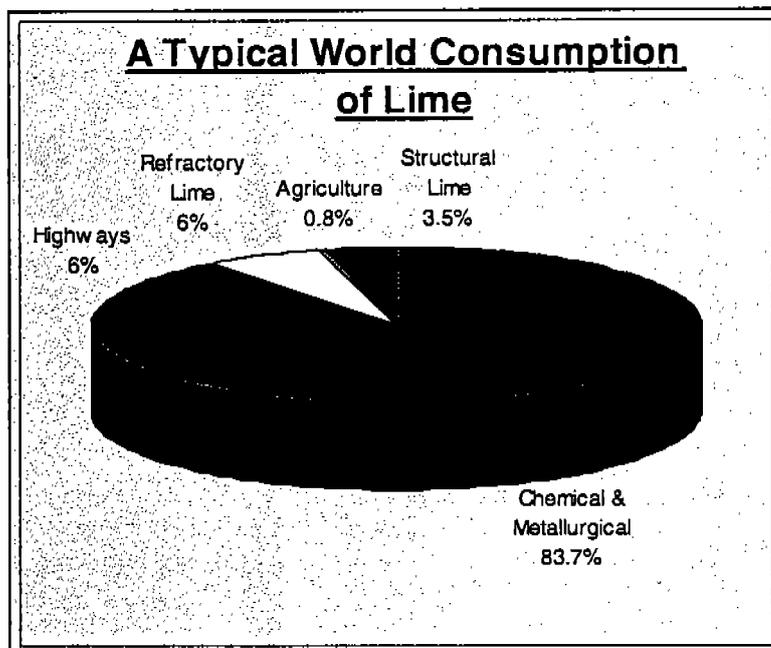
Component	Calcitic Lime	Dolomitic Lime
CaO	86.00 - 98.00	30.00 - 57.50
MgO	0.30 - 8.00	18.30 - 40.80
SiO <sub>2</sub>	0.20 - 1.50	0.80 - 1.50
Fe <sub>2</sub> O <sub>3</sub>	0.10 - 0.40	0.05 - 1.50
Al <sub>2</sub> O <sub>3</sub>	0.10 - 0.50	0.05 - 0.50
H <sub>2</sub> O	0.10 - 0.90	0.10 - 0.90
CO <sub>2</sub>	0.40 - 1.50	0.40 - 1.50



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**6.3.2 Applications**

There exists an extremely broad end use spectrum of lime and in industry it is the second largest "heavy" or basic chemical used after sulfuric acid. End market for lime can usually be divided in to three broad groups: chemical and industrial, construction, and agriculture. During the earlier part of the century lime was mainly used (>90%) for construction purposes. Today the world distribution of lime use is given below.



Lime is consumed for a wide variety of applications. The industries can be divided into the following categories as shown below.

World Lime Consuming Industries		
Chemical & Industrial	Metallurgical Chemical Manufacture Sanitation Pulp & Paper Ceramics Foods Petroleum Environmental Miscellaneous	Flux, refractory, non-ferrous floatation, and smelting Magnesia, alkalis, carbide, bleaches, inorganic, organic Water treatment, sewage, trade wastes Sulfate paper - causticising, bleaching Glass, refractories, bricks Sugar processing, dairy, citrus pulp grease, refining, drilling mud Flue gases, desulphurisation Paints, pigments, leather tanning, rubber, varnish,
Construction	Structural roads, airports	Mortar, plasters, stucco soil stabilization, asphalt, bases
Agricultural	Forests, fields	Soil liming, fertilizer, etc.

## HATCH

### ➤ Flux

Lime is added to the steel furnace as a flux which reacts with chemical impurities in the melt. This enables dry impurities to rise to the surface of the melt and form the slag. This can then be removed from the furnace or converter before pouring off the purified metal. The slags thus formed remove or control the level of acid components particularly silica, sulphur, and phosphorous inherent in iron ores, coals, scrap, and alloying agents, to tolerable levels in the later stages of steelmaking through to the final product.

Burnt lime was employed extensively in the electric arc furnace process, especially for the preparation of reducing slag. The properties of hard, medium, and soft burnt lime were recognized with closer attention given to analysis and size specifications in order to regulate quality of supply, avoid fine losses, and achieve processing consistency. With the advent of the autogenous oxygen converter the use of limestone as a steelmaking flux largely disappeared in favor of burnt lime. US lime consumption in a basic oxygen furnace is in the order of 40-85 kg short tons of steel and in an electric furnace is 30 kg per ton (part of it burnt dolomite). In the UK, the average burnt lime charged is around 55.9 kg per tonne with burnt dolomite 22.4 kg per tonne, mainly to enhance lining protection.

### ➤ Refractory

Dead burnt or hard burnt dolomite or refractory lime is used in both brick and shape manufacture and for monolithic refractories. To achieve refractory grade dolomite must be burnt to drive contained CO<sub>2</sub>. The material is sintered, hard burned or dead burned at elevated temperatures to produce a much denser, more inert product (dead or hard burned dolomite, refractory lime or doloma). The actual sintering temperature varies depending on the purity and properties of the material. The chemical composition and bulk specific gravity of the burnt product are the most important properties. The main refractory applications of dead burnt dolomite are as dolomitic bricks in BOF lining, steel ladles, ladle furnaces, VAD vessels, VOD vessels, AOD vessels, cement kiln, lime kilnsets, and as dolomitic monolithics in hot repairs of EAF bottoms, BOF, Fettler for joints, backfilling, etc.

The most important market for the dead burned material is open-hearth furnaces, basic oxygen furnaces, ladle linings, argon oxygen decarburization vessels, cement kilns, and some cases electric arc furnaces. Typical burnt material brick properties are given below.

**Typical Physical Properties of Dolomite Bricks**

	Dolomite Fired	Dolomite tar- bonded	Dolomite resin-bonded		Dolomite-carbon resin-bonded	
			Un-tempered	Tempered	Un-tempered	Tempered
Cold Crushing Strength(MPa)	40	35	55	100	25	35
Permeability (µm <sup>2</sup> )	0.15	0.00	0.00	0.00	0.00	0.00
Bulk Density (kg/m <sup>3</sup> )	2,850	2,920	2,970		2,650	
True Density (kg/m <sup>3</sup> )	3,337	2,990	3,085		2,750	
Total Porosity (%)	16.1	3.4	3.4		3.5	
Residual Carbon(%)	-	2.5	3.1		15.7	
Loss on Ignition (%)	-	4.7	4.7		17.4	
MgO(%)	36.0	39.0-40.0	39.0 - 40.0		39.0 - 40.0	
CaO(%)	61.0	57.0 - 58.0	57.0 - 58.0		57.0 - 58.0	
SiO <sub>2</sub> (%)	1.5	1.3	1.3		1.3	
Fe <sub>2</sub> O <sub>3</sub> (%)	1.0	0.7	0.7		0.7	
Al <sub>2</sub> O <sub>3</sub> (%)	1.0	0.8	0.8		0.8	

**HATCH**

The global market for the refractory dolomite is now supplied by just six companies, five of which are headquartered in Europe. Total world production of this group is around 2 million tonnes per annum dead burnt dolomite. The companies are Baker Refractories USA; Lhoist Group, Belgium; Laradus Vermögensverwaltung GmbH, Germany; Lafarge SA, France; Veitsch Radex AG, Austria; and Carmeuse, Belgium. All these companies are very large, well established in their field, have large operating facilities all over the world, and export the material worldwide. They also operate dolomite refractory plants so in a sense they are also captive dolomite producers.

**➤ Non-Ferrous Metallurgy**

Lime prevents the adverse effects of soluble salts on flotation by precipitating them as metal hydroxides, and is used to modify pH in beneficiation of metallic ores. It is also used extensively as a depressant for pyrite and arsenopyrite in beneficiating copper ore during flotation. There is limited use of lime as a flux in smelting concentrated copper ores. In the manufacture of alumina by the Bayer process, lime is used to causticize sodium carbonate solutions to regenerate sodium hydroxide for recyclical use.

Lime is also used in most processes involving the manufacture of magnesia and magnesium metal, e.g. the natural brine and sea water, ferrosilicon, and sea water magnesium processes. Dolomitic lime, owing to its high magnesium content, is usually preferred. Dolime burnt at 1,400 - 1500 C grading -20 mm, and lime burnt at 1600 C grading -40-+47 mm is suitable for sea water magnesia production.

**➤ Chemical Manufacture**

Quicklime is used in large quantities to recover ammonia in the manufacture of soda ash and sodium bicarbonate by the solvay process where some 635 kg of quicklime are required per short ton of soda ash. Calcium carbide, formerly the main source of acetylene, is manufactured through the fusion of quicklime and coke at very high temperatures. Chlorine and hydrated lime are reacted together to produce sources of dry bleach in the form of high-test calcium hypochlorite and chloride of lime. Other chemicals made from lime are calcium phosphates, chrome chemicals, pesticides, and paint pigments. Lime is also used in the manufacture of ethylene and propylene glycol, calcium based organic salts, refining citric acid and glucose, and dyes.

**➤ Pulp and Paper**

In the manufacture of Kraft paper or sulphate paper, lime is universally used to causticize waste sodium carbonate to regenerate sodium hydroxide for reuse. For example, in Finland the lime consumption is around 15-20 kg of lime per tonne of pulp. The Norwegian pulp industry reported the make-up lime to be in the order of 3,000-4,000 tpa to maintain two Kraft mills with capacities of 400-450,000 tpa. Calcium carbonate is extensively used as a filler in the paper industry and products produced in-house would certainly reduce costs of buying filler material elsewhere.

**➤ Environmental**

Flue Gas Desulphurization (FGD) has become a potential market for lime products where lime is used to remove sulphur dioxide from flue gasses of coal fired plants. There are different processes. Several types of throwaway processes are available such as wet scrubbing, dry



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scrubbing, and dry injection. Lime is used extensively in all these processes and wet and dry scrubbing are in wide commercial use. A summary of the FGD system/process is given below.

<b><u>A Summary of FGD System/Processes</u></b>	
<b>Throwaway Processes</b>	
<b><u>Wet Systems</u></b>	Lime Limestone Dual Alkali Sodium Carbonate
<b><u>Dry System</u></b>	Lime Sodium Carbonate
<b>Saleable Product Processes</b>	
	Lime (gypsum by-product) MgO (Sulphuric acid) Wellman Lord (Sulphuric acid)

Other Uses:

- **Sanitation:** Lime is used both in water and sewage treatment. In water treatment lime is used to soften the water by removing bicarbonate hardness.
- **Building Products and Glass:** The two main building products in which lime is used are dense bricks (sand lime bricks and blocks), and aerated bricks and blocks. In glass manufacture burnt lime products are not used in large extent owing mainly to reasons of economics. However, fine grained grades of dolomitic lime is used in fiberglass and to a lesser extent container glass.
- **Sugar Refining:** Lime is an essential chemical for the refining of both beet sugar and cane sugar. Lime assists in purifying the sucrose juices by removing phosphatic and organic acid compounds as insoluble calcium compounds which are removed by filtration. Cane sugar utilizes around 2-5 kg lime per tonne of sugar where as beet sugar requires around 0.2 tonnes of quicklime.
- **Soil Stabilization:** Soil stabilization with lime helps to turn unsuitable or marginal soil into construction materials which can be more easily placed and compacted to form the temporary or permanent works.
- **Agricultural:** Lime will neutralize soil acidity through base exchange with the calcium and magnesium cations displacing the hydrogen ions in the soil. This process results in a 15-40% increase in crop yield. The optimum grain size is less than 1.25 - 0.18 microns as a free flowing powder.

**6.3.3 Market Development**

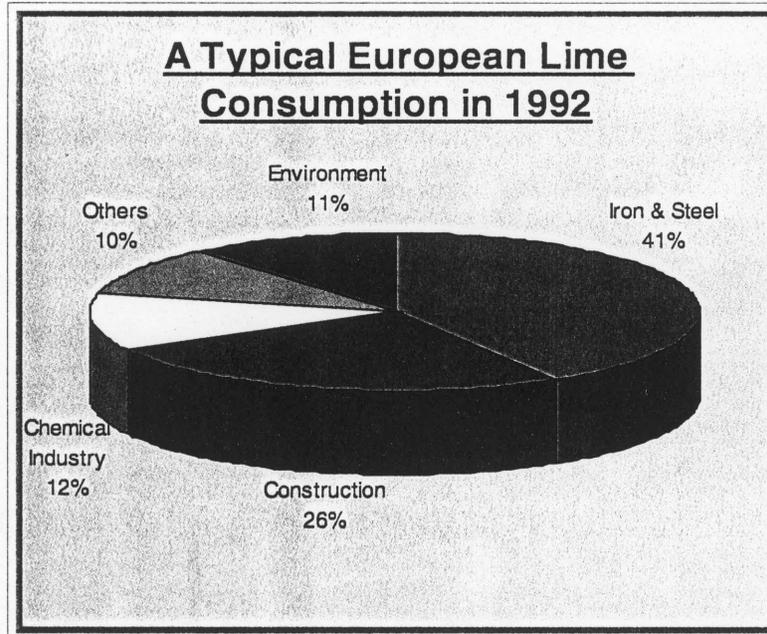
Although the various markets for lime are expanding or contracting due to a variety of factors, the single most important influence on lime consumption is the economy itself. Despite this, differing national practices mean that the amount of lime used by one country in a particular market differs drastically from the amount used in another country for the same purpose. An example of this is the soil stabilization market which is large in France and yet virtually non-existent in the UK.



**HATCH**

Limes many applications can be divided into three broad markets:

- Chemical and industrial
- Construction
- Agriculture



However, the use of lime in certain industries has declined while in others it has increased. Unfortunately the increases have generally been relatively small and have been insufficient to stave off the decreases. Examples of this shifting market include the decline in lime use by the steel industry while there has been an increase in the size of the construction market. Meanwhile, a relatively new market has emerged in the production of PCC for use in paper making. In this process lime is the main source of the calcium for the end product. Another area providing opportunities is in pollution treatment for the neutralization of acidic waste. There are also two major markets which can be considered separately from the rest of the lime industry because the producers generally manufacture their own lime. There is the sugar industry which utilizes lime in sugar refining process and synthetic-route soda ash producers.

#### **6.3.4 US Production**

The term "lime," as used throughout this chapter, refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. They are (1) quicklime, calcium oxide (CaO); (2) hydrated lime, calcium hydroxide [Ca(OH)<sub>2</sub>]; (3) dolomitic quicklime (CaO . MgO); two types of dolomitic hydrate; (4) type N [Ca(OH)<sub>2</sub> . MgO]; and (5) type S [Ca(OH)<sub>2</sub> Mg(OH)<sub>2</sub>]; and (6) dead-burned dolomite. Non-dolomitic quicklime and hydrated lime are also called high-calcium lime. Lime also can be produced from a variety of calcareous materials such as aragonite, chalk, coral, marble, and shell. Lime is also regenerated; that is, produced as a by-product, by paper mills, carbide plants, and water treatment plants; however, regenerated lime is beyond the scope of this report.



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Domestic production data for lime are developed by the U.S. Geological Survey (USGS) from two separate voluntary surveys of US operations. The survey used to prepare this report is the annual "Lime" survey. The annual survey form was revised for the 1997 data collection year in cooperation with the lime industry. Major revisions included the elimination of the shipments section and major changes to the end use and value sections. These revisions resulted in the elimination of the shipments table and a reorganization of the end use table. Value data are now collected by type of lime, i.e., high calcium or dolomitic, instead of by market segment as in the past. Value data are not collected by end use, so the value data shown in table 4 are determined by calculating the average value per ton of quicklime sold or used for each respondent and then multiplying it by the quantity of quicklime the respondent reported sold or used for each end use. The same calculation is performed for hydrated lime sold or used. Table 4 displays the total quantity sold or used for an end use and the total value of the quicklime and hydrate sold or used for that end use calculated as described above.

The USGS maintains a list of operations classified as producing or idle; currently there are 117 operations on this list. Six of these operations are not surveyed at the producers request and estimates are made using reported prior-year production figures or other industry data. Of the 111 operations to which the annual survey request was sent, 106 responded, representing 88% of the total sold or used by producers shown in Table 2. Production for five non-respondents was estimated using reported prior-year production figures.

At the end of 1997, there were 33 commercial lime producers operating 64 lime plants producing quicklime and 7 separate hydrating plants. This takes into account two producers that were idle in 1997, one plant that closed, one plant that was idle except for its hydrator, and a previously captive plant purchased by a commercial producer. There were 4 companies operating 4 plants that combined captive production and commercial sales, and 16 companies operating 39 plants producing quicklime strictly for captive use. The leading producing companies were all commercial producers with the exception of Martin Marietta Magnesia Specialties Inc., which is a combined captive and commercial producer.

In 1997, the top 10 companies were, in descending order of production, (1) Chemical Lime Co., with three lime plants in Alabama, two each in Arizona, Nevada, and Texas, one each in Idaho, Missouri, and Utah, and hydrating plants in California and New Mexico; (2) Dravo Lime Co., with two plants in Kentucky, one plant in Alabama, and a hydrating plant in Louisiana; (3) Mississippi Lime Co., with one plant in Missouri; (4) Marblehead Lime Co., with one plant each in Illinois, Indiana, and Michigan; (5) Continental Lime Inc., with one plant each in Montana, Nevada, Utah, and Washington; (6) Global Stone Corp., with one plant each in Michigan, Oklahoma, Tennessee, and Virginia; (7) APG Lime Co., with two plants in Virginia and one plant in Texas; (8) Martin Marietta Magnesia Specialties Inc., with one plant in Ohio; (9) Carmeuse Pennsylvania Inc., with two plants in Pennsylvania; and (10) Bellefonte Lime Co., with two plants in Pennsylvania. These 10 companies operated 35 lime plants and 5 separate hydrating plants and accounted for 75% of commercial sales of quicklime and hydrated lime combined and 67% of total lime production. Domestic lime plant capacity is based on 365 days minus the average number of days for maintenance times the average 24 hour capacity of quicklime production, including quicklime converted to hydrated lime, and reported in short tons per year. In 1997, capacity data were available from 34 commercial companies operating 49 plants. The calculations do not include combined commercial and captive producers, hydrating plants, plants that commissioned new kilns during the year, and Puerto Rico. Based on the available data, the US lime industry operated at 81% of capacity in 1997. This is about the same operating rate as 1996. Capacity utilization would be slightly lower if the capacity of several idle or mothballed plants were factored into the calculations.



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On a regional basis capacity utilization ranged from 69% to 90%. In the Middle Atlantic Region (plants in eastern and central Pennsylvania, West Virginia, and northern Virginia), capacity utilization was 83%, based on data from six companies operating eight plants. In the Southeast Region (plants in Alabama, eastern Tennessee, and southern Virginia), capacity utilization was 90%, based on five companies operating seven plants. In the Eastern Midwest Region (plants in Michigan, northern Kentucky, Ohio, and western Pennsylvania), capacity utilization was 89%, based on five companies operating six plants. In the Western Midwest Region (plants in Illinois, Indiana, Iowa, Missouri, and Wisconsin), capacity utilization was 80%, based on seven companies operating nine plants. In the South Central Region (plants in Arkansas, Louisiana, Oklahoma, and Texas), capacity utilization was 82% based on six companies operating eight plants. In the Western Region (plants in Arizona, Colorado, Idaho, Montana, Nevada, Oregon, South Dakota, Utah, and Washington), capacity utilization was 69%, based on 5 companies operating 11 plants.

In regional industry news in the Southeast Region, the A.P. Green Industries Inc.-SCANA Corp. joint venture to build a new lime plant in Charleston, SC, was delayed and start-up is now scheduled for late 1998. The plant will operate as Palmetto Lime LLC in conjunction with A.P. Green's subsidiary APG Lime. The plant is now expected to have an initial annual capacity of 254,000 tons (280,000 short tons), expandable to 381,000 tons (420,000 short tons), with installation of a second kiln (A.P. Green Industries Inc., 1998). Global Stone Tenn Luttrell Inc.'s Tennessee plant suffered operational delays during the summer due to severe flooding that occurred in late June. The plant's new Cimprogetti vertical shaft regenerative kiln came on-line and the company reported it would boost plant capacity by 30% (Global Stone Corp., 1997). Blue Circle Cement Co. completed most of the modernization and expansion work on its Roberta lime plant at Calera, AL, by year end 1997. Overall completion was scheduled for early 1998. The project replaced a trio of old kilns with a single Kennedy Van Saun preheater rotary kiln that boosted annual plant capacity to 363,000 tons per year (400,000 short tons per year). Chemical Lime completed start-up of its new O'Neal lime plant near Calera, AL. The new plant's annual capacity is about 400,000 tons (445,000 short tons).

Dravo Lime purchased a number of land parcels adjacent to its Longview Division quarry in Alabama that doubled its limestone reserves. The facility, which produces lime and aggregates, now has adequate reserves to last 45 years at present rates of extraction. In addition, Dravo Lime secured necessary permits and plans to add a fourth kiln at the Longview Division lime plant in Saginaw, AL. Construction on the new 270,000 ton per year (300,000 short tons per year) kiln will commence during the spring of 1998 and increase plant capacity by more than 50% when completed (Dravo Lime Co., 1998). Dravo Lime achieved ISO 9002 certification for the Longview lime operations (Sommer, 1997). Chemical Lime is reassessing plans for its announced processing plants and storage terminals in Charleston, SC, and Tampa, FL, due in part to the evolving rail situation in the southeast and to overall geographic considerations on how to best serve its long-term customers.

In the Middle Atlantic Region Corson Lime Co. closed its Plymouth Metting, PA, operations after 175 years in business. Corson Lime's assets were sold by its parent company, U.S. Lime and Minerals Inc., to Highway Materials Inc. (Rock Products, 1997). Medusa Corp., mainly a cement and aggregates company, purchased Lee Lime Corp. of Lee, MA. Lee Lime is a small producer of dolomitic quicklime and dolomitic hydrate (North American Mineral News, 1997a).

In Eastern Midwest Region, Marblehead Lime is beginning a \$20 million renovation and construction project at the Maple Grove, OH, plant acquired from American Premier in late 1997. The plant last operated in the early 1980's when its owner, Basic Inc., produced dolomitic



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lime and dead-burned refractory dolomite. Completion of the current renovation project is expected mid-1999 (North American Mineral News, 1998b).

Martin Marietta Magnesia Specialties completed Phase II of its capacity expansion project at its Woodville, OH, plant. Phase II increased total lime plant capacity to about 770,000 tons per year (850,000 short tons per year). Phase I, completed in 1996, increased capacity at the Woodville south plant and Phase II increased capacity at the north plant. The Ohio plant produces dolomitic quicklime for use at the company's magnesia plant in Manistee, MI, and sells to steel and related markets (North American Mineral News, 1998a). Dravo Lime boosted the annual capacity at its Maysville, KY, plant to 1,270,000 tons per year (1,400,000 short tons per year) by starting up a new kiln during the spring of 1997, and completed a major upgrade of the No. 3 kiln at its Black River plant in Carntown, KY (Dravo Lime Co., 1998b). Dravo achieved ISO 9002 Certification for the Maysville lime operations (Sommer, 1997).

In the Western Midwest Region, Marblehead Lime completed kiln and baghouse improvements that boosted capacity by 181,000 tons per year (200,000 short tons per year) to a total of 726,000 tons per year (800,000 short tons per year) at its Buffington, IN, plant (Rock Products, 1998). Vulcan Materials Co. started up its new dolomitic lime plant in Manteno, Kankakee County, IL. Mississippi Lime started construction on a Maerz twin vertical shaft parallel flow regenerative kiln that will produce 120,000 tons per year (132,000 short tons per year). Start-up of the new kiln is expected in the third quarter of 1998 (Mississippi Lime Co., press release, accessed February 13, 1998, at URL <http://www.mississippilime.com/whatsnew.htm>).

In the South Central Region, U.S. Lime & Minerals began a major modernization and expansion project at its Texas Lime Co. subsidiary in Cleburne, TX. The \$22 million project includes the installation of a new stone crushing and handling system, the addition of a preheater to one of the kilns, additional storage, screening and shipping capacity, and a new support building which will house laboratory, administrative, and shop facilities. The new preheater and the crushing system will increase the plant's lime production capacity by about 25% (United States Lime & Minerals Inc., 1998).

In the Western Region, Chemical Lime constructed a hydrating plant in Belen, NM. Chemical Lime also purchased the dolomite quarry, processing equipment, and lime plant in Natividad, CA, from National Refractories and Minerals Inc. (National Lime Association, 1998). Continental Lime installed a 900-ton-per-day (1,000-short-ton-per-day) rotary kiln at its Cricket Mountain plant near Delta, UT. This is the plant's fourth kiln, bringing the plant's total capacity up to 2,500 tons per day (2,750 short tons per day). The new kiln included a 14-ram Fuller-Continental style preheater (World Cement, 1997a).

Of the total number of US lime producers, about 17 produce dolime. Recently there has been a trend towards increasing consumption of Type S hydrated dolime (an ASTM designation for a structural hydrate) and some 400,000 tpa is used in building materials such as stucco. Chemstar Inc., for example, operates two plants at Salt Lake City and Las Vegas producing 130,000 tpa hydrated dolime for masonry material and construction, serving markets in the western USA. Although there has been an increase in demand for dolomitic quicklime as flux in the steel industry, particularly with the advent of the basic oxygen furnaces, there have been general cut-backs in raw material consumption. Furthermore, US steel production is not yet back to full capacity after recovering from its earlier strikes in 1986. In addition to dolime as a flux, the steel industry consumes refractory doloma in both brick lining grades and fettling grades. Recent statistics indicate that this market is showing a trend of increasing doloma consumption.



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There are only six dead burned dolomite producers in the US and of these, all produce refractory grade doloma except J. E. Baker Co. which is also the US' single producer of high quality doloma bricks. Most of the doloma producers manufacture dolime for flux and doloma for fettling grades in the steel industry. Martin Marietta Magnesia Specialties, which produced some 675,000 tons of dolime in early nineties at its Woodville, Ohio plant, produces flux lime for BOFs and dead burned dolomite for internal use to manufacture refractories via  $Mg(OH)_2$ .

### US refractory dead burned dolomite producers

National Refractories & Minerals Corp.  
Marblehead Lime Co.  
Resco Products of Missouri Inc.  
Martin Marietta Magnesia Specialties  
Ohio Lime Co.  
J. E. Baker Co.

J. E. Baker is currently experiencing a reduction in dead burned dolomite production owing to capacity restriction (the company has a crude dolomite output of around 1m. tpa) although it expects another record year for refractory brick production. Increasing applications have been found for these products in linings for ladles, ladle furnaces, and argon oxygen decarburizing vessels, and exports include products for cement kilns in the UK. In particular, J. E. Baker has found that zirconia, added as a secondary phase in doloma brick making, has been effective in increasing the thermal shock resistance of dolomite brick. Zirconia was chosen because it is relatively non-reactive with dolomite, and when a reaction does occur, stable calcium-zirconate forms. This type of product for linings has been favored by Japanese steel producers.

### **6.3.5 US Environment**

At the United Nations Framework Convention on Climate Change held in Kyoto, Japan, representatives from more than 150 countries agreed on measures that would obligate industrial countries to cut emissions of greenhouse gases. The list of greenhouse gases to be controlled include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

The accord, known as the Kyoto Protocol, would require the United States to reduce emissions of these gases 7% below 1990 levels (1995 levels for hydrofluorocarbons) by the year 2012 (United Nations Climate Change Secretariat, 1998). The Protocol, however, does not include an emissions trading system and major developing countries such as China, India, and Mexico did not sign the accord. Congress voiced its concern over the exclusion of developing countries from the Protocol and passed resolutions (House Resolution 4761 and Senate Resolution 98) requesting that the President not sign the Protocol or not submit it to Congress unless it is amended to include developing countries. The Protocol is an early step in the continuing attempt to deal with the causes of climate change, and any attempt will ultimately require the involvement of all countries.

The lime manufacturing process is heavily energy dependent and generates carbon dioxide as an unavoidable by-product. Limitations on carbon dioxide emissions or the application of a carbon tax would have a deleterious effect on the lime industry that would affect the steel, pulp and paper, construction, and environmental markets.



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### 6.3.6 US Consumption

The breakdown of consumption by major end uses was as follows: 40% for metallurgical uses, 26% for environmental uses, 24% for chemical and industrial uses, 8% for construction uses, and 1% for refractory dolomite. Captive lime accounted for about 12% of consumption and was used mainly in the production of steel in basic oxygen furnaces, in sugar refining, and in magnesia production. Almost all data on captive lime consumption, excluding the sugar industry, are withheld to protect company proprietary information.

In steel refining, quicklime was used as a flux to remove impurities such as phosphorus, silica, and sulfur. Dolomitic lime was often substituted for a fraction of the high-calcium lime to extend refractory life. Dead-burned dolomite, also called refractory lime, was used as a component in tar-bonded refractory brick used in basic oxygen furnaces. Lime consumption by the iron and steel industry increased by 5.4% to 6.05 million tons (6.67 million short tons). This continues the recent trend where lime consumption for iron and steel has increased faster than the production of raw steel which increased by about 3% in 1997. The steel industry accounted for about 31% of all lime consumed in the US.

In non-ferrous metallurgy lime was used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and maintain the proper pH in the flotation process. It was used to process alumina and magnesia, to extract uranium from gold slimes, and to recover nickel by precipitation. It was used in gold and silver recovery operations to control the pH of the sodium cyanide solution used to leach the gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitated tanks. Dump and heap leaching involves crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. Lime is used to maintain the pH of the cyanide solution at a pH level between 10 and 11 to maximize precious-metals recovery and to prevent the creation of hydrogen cyanide gas. Lime consumption for concentration of copper, gold, lead, silver, zinc, and other ores increased by about 5%.

The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Three of the four major treatment processes (Cyanisorb, alkaline chlorination, and sulfur dioxide/air) used to recover these cyanides use lime in the process.

In the environmental sector lime was used in the softening and clarification of municipal potable water. Lime was used to neutralize acid mine and industrial discharges. In sewage treatment lime's traditional role was to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aided clarification and killing of bacteria. More recently the largest use in sewage treatment has been to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, has as its goal the reduction of odors, pathogens, and putrescibility of the solids. In lime stabilization, the basic process involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time.

In FGD systems serving utility and industrial plants and incinerators, lime was used to react with sulfur oxides in the flue gas and was used to stabilize the resulting sludge before disposal. In 1997, the FGD market exhibited the first drop in demand since 1992 as consumption decreased slightly to 2.75 million tons (3.03 million short tons). Above normal winter temperatures and below normal summer temperatures in the Midwest resulted in lower electricity demand. Lower



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demand for electricity means lower demand for coal by utility companies and thus lower demand for FGD lime for scrubbing.

Lime is used by the pulp and paper industry in the basic Kraft pulping process where wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. The cooked wood chips (pulp) are discharged under pressure along with the spent liquor. The pulp is screened, washed, and sent directly to the paper machine or for bleaching. Lime is sometimes used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a recovery furnace where dissolved organics are burned to recover waste heat and where sodium sulfide and sodium carbonate are recovered. The recovered sodium sulfide and sodium carbonate are diluted with water and then treated with slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse.

The paper industry used lime as a coagulant aid in the clarification of plant process water. It was used generally in conjunction with soda ash for softening plant process water. This is a precipitation process to remove bivalent soluble calcium and magnesium cations (and to a lesser extent manganese, ferrous iron, zinc, and strontium), which contribute to the hardness of water. This process also reduces carbonate alkalinity and dissolved solids content.

Lime consumption for pulp and paper production, excluding precipitated calcium carbonate production, increased by more than 7% in 1997. This was a partial recovery from the 11% decrease reported in 1996 when consumption dropped to the lowest level since 1983.

Lime was used to make precipitated calcium carbonate (PCC), a specialty filler used in premium quality coated and uncoated papers, paint, and plastics. The most common PCC production process used in the United States is the carbonation process. Carbon dioxide is bubbled through milk-of-lime, a suspension of hydrated lime in water to form a precipitate of calcium carbonate and water. The reaction conditions determine the size and shape of the resulting PCC crystals.

The chemical industry used lime in the manufacture of alkalis. Quicklime was combined with coke to produce calcium carbide which was used to make acetylene and calcium cyanamide. Lime was used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk of lime was used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself was then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide was obtained as a by-product of lime production.

Dolomitic quicklime was used as a flux in the manufacture of glass. Quicklime was used to make calcium silicate building products such as sand-lime brick. Hydrated lime was used to produce silica refractory brick.

In construction, lime was used for soil stabilization to upgrade clay soils into satisfactory base and subbase materials. Common applications included the construction of roads, airfields, building foundations, earthen dams, and parking areas. Sales for soil stabilization increased by 6% when compared with the revised 1996 sales figures. The latter were revised downward to 1 million tons from the originally reported figure of 1.07 million tons. Quicklime was used in autoclaved aerated concrete to produce building materials that could be cut, drilled, and nailed like wood, but with the advantages of a concrete product. Hydrated lime was used with fly ash to make a base material in asphalt mixes to act as an anti-stripping agent and in plaster, stucco,



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and mortar to improve durability. Typical US lime production and distribution is shown in the table on the following page.

**SALIENT LIME STATISTICS 1/ (United States: 3/)**  
**(Thousand metric tons unless otherwise specified) 2/**

	1993	1994	1995	1996	1997
Number of plants	112	108 r/	106 r/	107 r/	105
<u>Sold or used by producers</u>					
High-calcium quicklime	NA	NA	NA	NA	14,300
Dolomitic quicklime	NA	NA	NA	NA	2,900
Total quicklime	14,200	14,800	15,800	17,000 r/	17,200
High-calcium hydrated lime	NA	NA	NA	NA	1,800
Dolomitic hydrated lime	NA	NA	NA	NA	352
Total hydrated lime	2,250	2,290	2,390	2,150 r/	2,150
Dead-burned dolomite	315	300	308	W	W
Grand total	16,700	17,400	18,500	19,200 r/	19,700
Value 4/ thousands \$	965,000	1,020,000	1,100,000	1,170,000r/	1,190,000
Average value per ton , \$	57.60	58.80	59.20	60.80 r/	60.70
Lime sold	14,900	15,500	16,400	16,800 r/	17,300
Lime used	1,870	1,910	2,180	2,430 r/	2,420
Exports 5/ 6/	69	74	72	50	80
Value thousands, \$	7,830	7,800	8,490	5,600	9,550
Imports for consumption 5/ 6/	201	204	289	262	274
Value thousands, \$	13,300	13,100	20,200	19,400	26,500
Consumption, apparent 7/	16,900	17,500	18,700	19,300	19,800
World: Production	123,000	120,000	121,000	121,000	120,000

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ To convert metric tons to short tons multiply metric tons by 1.10231.

3/ Excludes regenerated lime. Excludes Puerto Rico.

4/ Selling value, f.o.b. plant, excluding cost of containers.

5/ Bureau of the Census.

6/ For 1993 through 1996 data include quicklime, slaked lime, and hydraulic lime; data for 1997 also include calcined dolomite.

7/ Defined as sold or used plus imports minus exports.

The following table discusses the lime application for various industrial uses in the US. The price per tonne material can be calculated by dividing the price with tonnage.

**LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/**  
**(Thousand metric tons and thousand dollars) 3/**

Use	1996		1997	
	Quantity 4/	Value	Quantity 4/	Value
Chemical and industrial:				
Fertilizer (aglime and fertilizer)	26	2,190	24	1,790
Glass	159	8,930	141	9,130
Paper and pulp	908	56,700 r/	976	60,200
Precipitated calcium carbonate	774 r/	43,800 r/	868	51,800
Sugar refining	655	47,100 r/	748	55,100
Other chemical and industrial 5/	1,950 r/	116,000 r/	2,080	126,000
Total	4,480	275,000	4,840	304,000
Metallurgical:				



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**LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE 1/ 2/  
(Thousand metric tons and thousand dollars) 3/**

Use	1996		1997	
	Quantity 4/	Value	Quantity 4/	Value
Steel and iron:				
Basic oxygen furnaces	4,000 r/	227,000 r/	4,380	249,000
Electric arc furnaces	1,160 r/	67,300 r/	1,330	82,300
Other steel and iron	578	37,000	348	21,300
Total	5,740 r/	331,000	6,050	353,000
Nonferrous metals:				
Aluminum and bauxite	237	14,800	216	13,200
Other nonferrous metallurgy 6/	1,550	86,900	1,620	89,700
Total nonferrous metals	1,790	102,000	1,840	103,000
Total metallurgical	7,530	433,000	7,890	456,000
Construction:				
Asphalt	137	11,000 r/	237	18,900
Soil stabilization	1,000 r/	63,300 r/	1,060	65,000
Building uses 7/	298	27,600	314	33,700
Other construction 8/	71	9,790 r/	18	1,310
Total	1,510 r/	112,000 r/	1,630	119,000
Environmental:				
Flue gas sulfur removal:				
Utility power plants	2,660	150,000	2,590	133,000
Incinerators	121	7,200	108	6,630
Other	32	1,960	56	3,560
Total	2,810 r/	159,000 r/	2,750	143,000
Sludge treatment:				
Sewage	NA	NA	335	23,000
Other (ind., hazardous, etc.)	NA	NA	96	6,310
Total	NA	NA	430	29,300
Water treatment:				
Acid mine drainage	NA	NA	172	11,500
Drinking water	NA	NA	895	56,600
Wastewater	NA	NA	485	30,700
Total	NA	NA	1,550	98,800
Other environmental: 8/	2,630	163,000	309	20,100
Total environmental	5,440	323,000 r/	5,040	291,000
Refractories (deadburned dolomite)	W	W	W	W
<b>Grand total</b>	<b>19,200 r/</b>	<b>1,170,000 r/</b>	<b>19,700</b>	<b>1,190,000</b>

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Excludes regenerated lime. Includes Puerto Rico.

2/ Data are rounded to three significant digits; may not add to totals shown.

3/ To convert metric tons to short tons multiply metric tons by 1.10231.

4/ Quantity includes lime sold and used, where "used" denotes lime produced for internal company use for copper ore concentration, magnesia, paper and pulp, precipitated calcium carbonate, basic oxygen furnaces, mason's lime, and refractories.

5/ The 1996 and 1997 data are not directly comparable, in 1996 "Other chemical and industrial" included metallurgical uses.

6/ Includes ore concentration (copper, gold, etc.), magnesium, and other.

7/ The 1996 and 1997 data may not be directly comparable, because the 1996 data only included mason's lime and finishing lime.

8/ The 1996 and 1997 data may not be directly comparable.

**HATCH**

World production of lime compiled by a US geological survey is given below (1998 statistics are not available yet).

**QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE:  
WORLD PRODUCTION, BY COUNTRY 1/ 2/**

	(Thousand metric tons)				
Country 3/	1993	1994	1995	1996	1997 e/
Australia e/	1,500	1,500	1,500	1,500	1,500
Austria	1,811	1,850	1,908 r/	1,990 r/	1,900
Belgium e/	1,750	1,750	1,800	1,800	1,800
Brazil e/	5,700	5,700	5,700	5,700	5,700
Bulgaria	531	665	952	1,000 e/	1,200
Canada	2,380	2,390 e/	2,398	2,402 r/	2,447 p/
Chile (hydraulic) e/	1,300	1,300 r/	1,006 4/	1,050	1,050
China e/	19,500	19,500	20,000	20,000	20,500
Colombia e/	1,300	1,300	1,300	1,300	1,300
Czech Republic	1,147	1,206	1,186	1,176 r/	1,200
France	3,000 e/	3,015	2,940	2,714 r/	2,800
Germany	7,483	8,511	8,000 e/	8,000 e/	8,000
Italy e/ 5/	3,600	3,500	3,500	3,500	3,500
Japan (quicklime only)	7,958	7,712	7,871 r/	7,744 r/	7,850
Mexico e/	6,500	6,500	6,580 4/	6,600	6,600
Poland	2,584	2,516	2,526	2,500 e/	2,500
Romania	1,738	1,621	1,763 r/	1,712 r/	1,750
South Africa (sales)	1,599	1,597	1,743	1,691	1,585 4/
U.S.S.R., Former e/ 6/	20,000	16,000	16,000	15,000	14,000
United Kingdom e/	2,500	2,500	2,500	2,500	2,500
United States, including Puerto Rico (sold or used by producers)					
	16,800	17,400	18,500	19,100	19,700 4/
Other e/	12,300 r/	12,000 r/	11,600 r/	11,700 r/	11,700
<b>Total</b>	<b>123,000</b>	<b>120,000</b>	<b>121,000</b>	<b>121,000</b>	<b>120,000</b>

e/ Estimated. p/ Preliminary. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through June 3, 1998.

3/ Lime is produced in many other countries besides those included in the total. Argentina, Iraq, Pakistan, and Syria are among the more important countries for which official data are not available.

4/ Reported figure.

5/ Includes hydraulic lime.

6/ Information is inadequate to formulate reliable estimates for individual countries of the former U.S.S.R.

**6.3.7 US Market Prices**

The average values per ton of lime rounded to three significant figures are discussed in dollars per metric ton with accompanying conversions into dollars per short ton. For accuracy the conversions were made from the unrounded metric value, and as a result may not be an exact conversion of the rounded values. Starting with the 1997 data collection year, all value data for lime will now be reported by type of lime produced rather than by market use as in the past. The average value per ton of high-calcium quicklime, high-calcium hydrate, dolomitic quicklime, dolomitic hydrate, and dead-burned dolomite will be listed. Emphasis will be placed on the average value per ton of lime sold as in the past.



## HATCH

The average unit value of all lime sold or used by producers on an f.o.b. plant basis decreased in 1997 to \$60.70 per ton (\$55.00 per short ton). Average values per ton were \$57.80 (\$52.40 per short ton) for quicklime, \$80.20 (\$72.70 per short ton) for hydrated lime, and \$87.70 (\$79.60 per short ton) for refractory dolomite. The average value of quicklime sold was essentially unchanged at \$56.60 per ton (\$51.40 per short ton). The average value per ton of high-calcium quicklime sold was \$56.70 (\$51.40 per short ton). The average value per ton of dolomitic quicklime sold was \$56.40 (\$51.10 per short ton). The average value per ton of refractory dead-burned dolomite sold decreased slightly to \$87.30 (\$79.20 per short ton). The average value per ton of hydrated lime sold increased slightly to \$80.40 per ton (\$73.00 per short ton). The average value per ton of high-calcium hydrate sold was \$75.70 (\$68.60 per short ton). The average value per ton of dolomitic hydrate sold was \$104.60 (\$94.90 per short ton). The high dolomitic hydrate value is characteristic of high-value specialty products such as mason's lime which is more expensive to manufacture (requires pressure hydration) and is frequently shipped in bags.

### 6.3.8 US Foreign Trade

The United States imported and exported quicklime, hydrated lime (slaked lime), hydraulic lime, and calcined dolomite (dolomitic lime). Combined exports of lime were 79,800 tons (88,000 short tons) at a total value of \$9.55 million, with 63% going to Canada, 21% going to Mexico, 6% going to Suriname, 4% going to Trinidad and Tobago, and 2% each going to Indonesia and Jamaica. Combined imports of lime were 274,000 tons (302,000 short tons) at a total value of \$26.5 million, with 94% coming from Canada and 5% coming from Mexico.

## 6.4 World Review

### 6.4.1 Australian Lime Industry and Situation

Over the years Australian lime production remained unchanged. In 1997, Australia produced around 1.5 million tons of lime according to the Minerals Industry of Australia which is approximately the same amount as that produced in 1993.

Recently, Western Australia is undergoing a surge in lime plant construction because of strong demand by the alumina, gold, and synthetic rutile industries. Three of the four Western Australia lime companies are adding capacity. Cockburn Cement Ltd., part of the Rugby Group PLC, is Australia's largest manufacturer of quicklime from its base in Western Australia. In 1997, Cockburn Cement was involved in major upgrades to its lime production facilities at Munster and Dongara. At Munster, the company installed a 400,000 ton per year (440,000 short ton per year) Fuller/FLS calcining system that incorporates a multistage preheater cyclone and flash calcination with a short rotary kiln. Start-up of this kiln took place in the spring of 1997. Feedstock for the kiln is dredged shells and that is screened, washed, and then pumped 7 kilometers from the coast to the Munster facility.

At Dongara, the company installed a Krupp-Polysius preheater lime kiln designed to produce 350 tons per day (385 short tons per day). Feedstock will be limesand mined from limesand dunes adjacent to the site. The limesand will be transferred by conveyor belt to a hopper, then dried and beneficiated to reduce silica content, put through the four-stage preheater, and then calcined in the rotary kiln. Start-up of the Dongara kiln was expected in the first quarter of 1998 (World Cement, 1997a).

**HATCH**

Westlime Ltd. also constructed a quicklime plant near Dongara. Construction of the 120,000 ton per year (132,000 short ton per year) plant was completed in late 1997 with start-up scheduled for the first quarter of 1998 (Department of Resources Development, Commissioned projects, accessed July 21, 1998, at URL <http://www.drd.wa.gov.au/pcommiss.htm>). Feedstock for the plant will be limesand from dunes near the site.

Swan Cement Ltd. is constructing a 100,000 ton per year (110,000 short ton per year) vertical shaft lime kiln near Kwinana (south of Perth). The plant will be supplied by limestone mined at Exmouth on the north coast about 1,000 kilometers north of the plant site. The stone will be transported to the plant by water. The lime plant is scheduled for completion in mid-1998 (Acted Consultants, Lime [Calcium oxide], accessed February 5, 1998, at URL <http://www.vianet.net.au/~acted/lime.htm>).

Burnt lime production in Australia is dominated by David Mitchell Ltd which operates quarries and lime manufacturing plants at Lilydale and Buchan in Victoria, Mole Creek in Tasmania, Townsville, Gympie, and Riverton in Queensland, and Attunga, Tabulam, and Sherwood in New South Wales. Main markets for burnt lime include the steel industry, paper manufacturing, and non-ferrous metallurgy in the form of an alkali for uranium and gold recovery (David Mitchell assisted in developing a new lime kiln for Bougainville Limestone Mining Pty Ltd and provides the essential lime required by the huge copper mine at Bougainville.) Other market uses include sugar refining, agricultural liming, glass making, soil stabilization, and industrial waste neutralization.

David Mitchell owns two further subsidiaries, Calcium Products Pty Ltd, primarily involved in the manufacture and distribution of lime products to the Queensland sugar and mining industries, and Darley Refractories Pty Ltd, a major manufacturer of refractory products in Victoria.

Taramee Lime Pty Ltd is a small producer of a range of industrial limestone products from mines at Murgon, South Burnett (15,000 tpa for chemical uses) and Gympie, North Coast (20,000 tpa for aggregates). In 1985 a coal-fired fluid bed calciner and lime hydrator was commissioned and began operating in early 1986. Burnt lime is sold for sugar refining, soil stabilization, and foundry and refining use, while hydrated lime products are used for water treatment and soil stabilization. The only other producer of note is Swan Portland Cement Ltd, which produces hydrated lime from purchased quicklime supplied by Cockburn Cement Ltd (part of Rugby Portland Cement PLC of the UK).

#### **6.4.2 Rest of the World Lime Industrial Situation**

##### **➤ United Kingdom**

The production of lime in the UK in the early nineties stems from seven burnt lime producers, one burnt dolomite producer, and two captive lime producers (see table). Although some information has been withheld from the table of burnt lime consumption by end use, it can be seen that almost 50% of lime is consumed in the steel industry. These products include burnt lime, dolomitic lime, and dead burned dolomite. Steetley Quarry Products Ltd is the UK's sole producer of calcined dolomite products, which are destined for the domestic steel industry, in-house seawater MgO production, and for exports. The UK producers of burnt lime products in the early nineties are given below with their capacities and end use.

**HATCH**

**UK producers of burnt lime products in early nineties**

Producer	Location	Capacity*	End use
ICI PLC	Tunstead	BL 500,000	steel, chemicals
		HL 270,000	sugar processing,
Singleton Birch Ltd	Hindlow	BL 200,000	water treatment
	Melton Ross	BL 300,000	steel, sugar,
		HL 25,000	chemical
		ML 25,000	water, effluent, building aerated blocks, stabilization
Tilcon Holdings Ltd	Swinden	BL 70,000	steel, 65% for hydration
Peakstone Ltd	Hindlow	BL 190,000	water, chemical, sugar
ARC Ltd	Cheddar	BL 180,000	steel
Totternhoe Lime & Stone Co. Ltd	Totternhoe	BL 36 tpd	stabilization
		HL 16 tph	mortar, neutralization
Hargreaves Quarries Ltd	Kirkby	BL 120 tpd	steel, HL
	Stephen		construction neutralization
British Sugar PLC	13 plants	BL 300,000	sugar refining
BSC	Shap	BL 6-7,000 tpw	steelmaking
Steetley Quarry Products Ltd.	Thrislington	DL 400,000	seawater MgO,
	Whitwell	DBL 250,000	steel steel

\* Capacity refers to tpa unless otherwise indicated.

BL burnt lime; HL hydrated lime; ML microlime; a very fine powdered lime; DL dolime; DBL dolime and dead burned dolomite.

The steel industry has historically been the major user of burnt lime, but in recent years demand has fallen with the decline of British steel production. This more recent increase in demand, and thus demand for raw materials, is shadowed by an overall trend in reduction of lime consumption in order to produce higher quality steels with lower amounts of silica and phosphorus. Hot metal silicon levels have reduced from a range of 0.88-1.1% Si in 1975 to today's level of less than 0.6% Si.

Other trends have included a move away from using lump lime to powdered lime, and preference for dolomitic lime. UK steel industry consumes an average of 9.1-20.5 kg of dolime per tonne of steel, seeking to achieve between 6-8% MgO in the hot metal mix. In hot metal desulphurization, favored reagents include calcium carbide/lime mixtures or powdered lime, alone or with alumina. The preferred size range is <150µm at injection rates of 30-50 kg per minute. With an addition of at least 4 kg per tonne, hot metal sulphur contents are reduced to <0.02 S.

Another increasing trend is the use of powdered lime in synthetic slags in ladle furnaces during secondary steelmaking. This is a kind of secondary refining process seeking to complete desulphurization and effect modification of residual sulphides and oxides to ensure that they adopt a globular shape more amenable to stringent property demands. Steel is tapped into a refractory ladle with as little slag carry-over from the primary steelmaking vessel as possible followed by the injecting or stirring in of a basic synthetic slag mixture of 70-85% powdered lime,



## HATCH

plus 15-30% fluorspar, with or without additions of alumina. An addition of 1-5 kg per tonne of synthetic slag is typical for ensuring sulphur content of less than 0.002% in the final product.

With the increasing trend toward secondary steelmaking it follows that there will be a rising demand for ladles and ladle furnaces, and this has been reflected in an increased demand for refractory dead burned dolomite bricks in extending ladle lining life. Doloma, together with zircon and alusite, has replaced traditional refractories such as bloating clays.

Sugar refining remains dependent on lime, although in this captive market British Sugar PLC produces its own quicklime for the larger of the two consuming sugars, beet sugar. There has been some decline in beet sugar demand (2-3% per annum) due largely to consumer fashion, but sugar production must be maintained to its EEC quota level of around 1.144m. tpa. Cane sugar, produced by Tate & Lyle PLC, consumes about 5-6,000 tpa of quicklime which is purchased from one of the main lime producers. The quicklime is slaked, subjected to CO<sub>2</sub> flue gas injection, converted to a chalky slurry and then employed to clarify the sugar which is subsequently recovered from the slurry. At present, UK cane sugar production (averaging 1m. tpa) is at full capacity.

The future outlook indicates a moving away from dependence on the steel industry to other growing markets and new end uses. These can be narrowed down to soil stabilization, agriculture, and the brick industry, and to a lesser extent water/effluent treatment, asphalt, and FGD.

Lime will continue to be used in water/effluent treatment and in asphalt. Indeed, Department of Transport specifications declare that in all gravels for asphalt manufacture, bar limestone gravels, 2% hydrated lime or Portland cement must be used. The lime acts as a binder and anti-stripping agent, particularly in quartz gravels. However, certain asphalt companies are looking to chemical or bitumen and tar substitutes owing to problems of handling and extra costs for filler silos. FGD applications for lime appear slim for the UK, with most processes requiring a limestone slurry, rather than lime, for the limestone gypsum method or the Wellman-Lord method (see earlier section).

Soil stabilization appears the best bet for the UK lime market and is currently enjoying a positive response from most in the lime industry, although with much construction already completed on UK clayland (i.e. the south, Thames basin) and an already developed road system, some may think that the stabilization practice already widely accepted in other nations has arrived too late in the UK. However, increasing use of this process can only help the lime market. Likewise, the agricultural market will take up a greater share of lime, particularly for regulating pH on farmland, streams and lakes, and generally combating the widely recognized effects of acid rain. There is scope for lime in fish farming since fish require calcium for nutrition as well as to inhabit a satisfactory pH environment.

The building industry, already using lime in soil stabilization is a growth market for lime use in calcium silicate bricks, particularly dense bricks and aerated bricks which have been helped by an increased interest in thermal insulation. Of building materials consuming lime in the UK, some 120,000 tonnes is reported to have been used in aerated blocks and calcium silicate blocks, 12-14,000 tonnes for plaster, and perhaps some 20,000 tonnes sold by builders and merchants. A typical UK production end use, exports, is given in the following tables.



**HATCH**

**UK sales of material for burnt lime production by end use, in 1988 ('000s tonnes)**

Use	Limestone	Dolomite	Chalk	Total	Of which for conversion by calcination	Estimation** of burnt lime
Agricultural	1,339	1,165	637	3,141	*	-
Iron and steel	2,005	8	*	3,992	2,021	1,010
Glass-making	266	104	-	370	-	-
Asphalt filler	320	136	1	457	-	-
Other fillers	767	72	347	1,186	-	-
Chemical use	*	8	*	1,923	1,923	961
Building materials	478	-	136	614	614	307
Other uses	*	8	*	384	*	-
<b>Total</b>	<b>7,047</b>	<b>3,085</b>	<b>1,935</b>	<b>12,067</b>	<b>4,793</b>	<b>2,278</b>

\* Withheld to avoid disclosure.

- Nil or less than half the final digit shown.

\*\* Amount of rock for calcination divided by 2 for burnt lime estimation

Source: Business Monitor PA1007

**Major UK Burnt Lime (calcined dolomite) Exports, 1986 (tonnes)**

Irish Republic	772
Greece	1,054
Portugal	1,699
Norway	1,138
Sweden	22,755
Finland	745
Taiwan	1,778
Philippines	993
Indonesia	2,966
Australia	969
New Zealand	1,937
EEC total	4,345
Non-EEC total	34,917
<b>All countries total</b>	<b>39,262</b>

Source: UK Customs and Excise Statistical Office

**Major UK slaked lime exports (tonnes)**

France	5,749
Sudan	2,116
Ivory Coast	5,513
Nigeria	1,959
Canada	1,936
Trinidad; Tobago	3,708
EEC total	6,659
Non-EEC total	17,681
<b>All countries total</b>	<b>24,340</b>

Source: UK Customs and Excise Statistical Office

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### ➤ New Zealand

In New Zealand, Mintech (NZ) Ltd, which produces some 15,000 tpa uncalcined dolomite, is looking to develop production of calcined dolomite for use in the steel industry. Current indications are of a requirement of 5,000 tpa calcined dolomite. This market appears to be expected to provide some potential for the dolomite industry; however, it is subject to competition from raw materials from China.

### ➤ Canada

Canadian production of lime has fluctuated around the 2m. tpa mark over the last few years. In the early nineties, geographical production of lime was - New Brunswick and Manitoba 7%, Quebec 13%, Ontario 67.4%, Alberta 7.3%, and British Columbia 5.3%. At that time there existed some 19 producers of lime including 10 captive producers (4 sugar, 4 steel, 1 carbide, 1 chemical).

Steetly Resources Ltd, which also owns Ohio Lime Co., in Woodville, Ohio produces some 400,000 tpa of dead burnt dolomite, dolime, and refractory lime from its Dundas, Ontario, plant. These products are destined mainly for the metallurgical and glass industries. In fiberglass manufacture, end-product specifications for MgO have been reported in the order of 4% MgO, thus maintaining some demand for high-magnesium or dolomitic quicklime grades. However, in the iron and steel industry, the continuing drive to push down concentrations of impurities such as silicon (down to 0.5-1.1% Si), sulphur, and phosphorus have resulted in an overall cut-back in lime and dolime consumption.

Markets outside Quebec and Ontario are usually served by only one or two local producers, e.g. Havelock Lime Works Ltd, which operate a 500 tpd lime kiln at Havelock, New Brunswick. The calcined and hydrated lime markets in the Atlantic region of Canada, which are served by Havelock, are relatively small and include the pulp and paper mills of eastern Canada, the mining sector, and a variety of water treatment plants.

### ➤ Cyprus

Hellenic Mining Co. Ltd is the only producer of burnt lime and hydrated lime in Cyprus. The lime plant is situated near Mitsero, about 22 miles south-west of Nicosia, and has a capacity of about 55 tpd although it is currently only operational around four months per year. Total sales, for local construction purposes, amount to about 7,000 tpa with only small quantities being exported. At present there is no market for burnt lime in Cyprus.

### ➤ Chile

Annual lime production amounts to about 900,000 to 1,000,000 tons per year. About two-thirds of this is produced captively by, in descending order, the mining industry (mainly gold and copper), pulp mills, and sugar mills. Over 90% of commercial sales go to the mining industry, and the remaining sales go to agriculture, construction, and environmental control. Captive producers are Comisión Chilena del Cobre (the Government copper company), Compañía de Acero del Pacífico, Carbomet, Compañía Manufacturera de Papeles y Cartones, Celulosa Constitución, and Industria Azucarera Nacional. Most commercial sales are from plants operated by Industria Nacional de Cemento S.A. and Sociedad Productora de Cal; these two account for 91% of sales. With major increases in gold and copper mining planned for the next few years, the commercial lime sector is expected to double its capacity to 600,000 tons to meet the increased demand (Gajardo, 1997).

## HATCH

### ► Finland

Partek Nordkalk AB announced a decision to construct a new kiln at its Tytyri lime plant at Lohja. The new kiln will have a capacity of 140,000 tons per year (154,000 short tons per year) and will cost FIM 70 million (about \$13 million). A considerable part of the expanded production will go to the new precipitated calcium carbonate plant at Myllykoski (Partek Corp., press release, accessed July 22, 1998, at URL <http://www.partek.fi/>). Partek Nordkalk signed an agreement with SSAB Tunnpått AB to acquire the lime plant that operates at the SSAB Tunnpått's steel mill at Luleå, Sweden, by yearend 1997. Limestone for the lime plant has been supplied for several years from Partek Nordkalk's quarry in Gotland, Sweden. Most of the plant's future lime production will still go to SSAB Tunnpått's steel mill, but excess production will be used to supply growing mining and pulp markets (Partek Corp., press release, accessed July 22, 1998, at URL <http://www.partek.fi/>).

At the Pargas plant, a coal-fired rotary kiln of 200 tpd produces burnt lime from limestone delivered by Nordkalk AB, Götland in Sweden, which is 50% owned by Partek. Products from Pargas are mainly for use in the steel and cellulose industries and for FGD. Soft-burned, high quality and high reactive lime is delivered in several fractions and ground lime is also available. At Lappeenranta, Partek owns two coal-fired rotary kilns of 250 tpd capacity. Both kilns use Precambrian limestone from the Lappeenranta quarry which yields a hard burnt lime product. This particular lime product is most suitable for the manufacture of precipitated calcium carbonate (PCC) used in paper manufacture and which requires a brightness of 94-96% (ISO). As well as quicklime, Lappeenranta also produces slaked lime products containing 92% and 97.5% Ca(OH)<sub>2</sub>. Special grades in the fraction range of 0-1mm are also available for metallurgical purposes. Ruskealan Marmori Oy, acquired by Partek, produces burnt lime at Kerimaeki (200 tpd) from the same type of limestone as at Lappeenranta. Around 60% of production is sold as unslaked lime, the rest consisting of slaked lime grades for building materials, chemicals manufacture, and environmental purposes.

The limestone production from mines at Tytri (underground - 900,000 tpa) and Mustio (open pit - 300,000 tpa) in early nineties. Some 60% of the mine's production is employed in cement manufacturing at the Virkkala cement plant. Burnt lime is produced at the Tytri plant (80,000 tpa) with 40,000 tonnes (170 mesh) for sand lime bricks and soil stabilization; 30,000 tonnes of hydrated lime for waste water treatment and industry; and 10,000 tonnes (1-10mm) for waste and waste water treatment. Other major markets for Partek include metallurgy (steel and colored metals), pulp and paper, and environmental conservation. Over the next few years a slight decline in the metallurgical market is expected, while a small increase is expected for the environmental market.

The use of PCC in the paper industry is expected to provide additional sales for lime. Partek is particularly involved in this segment of the market with its high quality raw material from Lappeenranta and PCC technology (acquired by license granted by Tervakoski Oy, an affiliate of the Enso-Gutzeit group producing 1.7m. tpa paper). Partek has been given the contract to plan a new 80 tpd plant for Tervakoski.

Within the pulp industry, i.e. manufacture of sulphate (Kraft) paper which in Finland consumes 15-20 kg of lime per tonne of pulp, Partek has developed applications expected to result in higher volumes of make-up lime. It is possible to use some of the excess lime mud, resulting from kraft pulp processing, in the manufacture of calcium carbonate filler material for use in paper and thus incur a saving on purchasing costs.

**HATCH**

➤ **Belgium**

There are three main producers of burnt lime products in Belgium - the Lhoist Group, Carrieres et fours a Chaux de la Meuse SA (Carmeuse), and the captive producer Solvay & Cie SA. Details of plants belonging to the Lhoist group are summarized in the accompanying table.

**Lhoist lime plants in Belgium, Early nineties**

<b>Company</b>	<b>Plant</b>	<b>Capacity and products (tpa)</b>
SA Leon Lhoist	Jemellè	BL, HL 450,000
SA Carrieres et Fours à Chaux Dumont-Wautier	Hermalle sous-Huy	BL, HL 800,000
SA des Dolomies de Marche-les-Dames	Nameche	SBD 500,000 DBD 200,000

BL burnt lime; HL hydrated lime; SBD soft burnt dolomite; DBD dead burnt dolomite

Burnt lime and hydrated lime products are consumed by steel, chemicals, agriculture, road, water treatment, sludge treatment, FGD, and dechlorination. Calcined/soft-burned dolomite products are destined for the steel, chemical, and agricultural industries, whilst dead-burnt dolomite is used as a refractory in the steel industry.

Carmeuse produces burnt lime from Seilles, Moha, and Aisemont, which have a combined burnt lime capacity of 1m. tpa although current production is around the 715,000 tpa mark. Grades produced include lump, granulated, ground, fine ground quicklime, and hydrated lime. All major end uses for lime consumption are served, and products are destined mainly for Benelux, although France, West Germany, Scandinavia, Africa, and the Middle East are targeted.

Solvay & Cie is one of the top ten producers of soda ash, the manufacture of which employs the use of lime (see section on applications). Solvay therefore produces burnt lime and hydrated lime at most of its soda ash plants, and in Europe this amounts to a capacity to produce a massive 4m. tpa of lime depending on the current state of the soda ash market.

➤ **Sweden**

Svenska Mineral AB is Sweden's main producer of burnt lime and dolomite products, and currently operates three plants - Gåsgruvan, near Filipstad in county Värmland, and Boda Kalkverk and Rattviks Kalkverk in county Dalarna. Current capacities and production are:

- Gåsgruvan           - 22,000 tonnes burnt lime
- 20,000 tonnes burnt dolomite
- Boda Kalkverk       - 100,000 tonnes burnt lime
- Rattsvik Kalkverk   - 40,000 tonnes burnt lime

There exists spare capacity of another 125,000 tonnes in three different rotary kilns of some 40,000 tonnes each which can produce both burnt lime and dolomite. Svenska possesses the limestone deposits to feed these kilns but is still seeking satisfactory markets.



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Also in Sweden, Larsbo Kalk AB, a subsidiary of Ernstrom Mineral AB specializes in the mining and processing of dolomite and limestone from deposits at Stora, north of Orebro. Some of the dolomite is calcined in shaft kilns to produce a sintered dolomite product for use particularly in the iron and steel industry.

The future outlook for lime appears grim, with tougher competition expected owing to decreases in demand from the iron and steel industry, more stringent product requirements from consumers, and a slow increase in other markets such as flue gas cleaning and waste water treatment.

### ➤ South Africa

There are three independent lime producers of significance in the Republic of South Africa - PPC Lime Ltd, Union Lime Co. Ltd, and Cape Lime Co. Ltd. Four market sectors also have captive lime production.

Water treatment - where the carbon dioxide released in the lime burning process is used further in the treatment process.

Paper production - where calcium carbonate is a by-product, affording the opportunity to recycle.

Sugar refining - where the carbon dioxide is used in the refining processes.

Steel industry - dolomitic lime for refractory and metallurgical uses is produced by Iscor Ltd (South African Iron & Steel Corp. Ltd)

In most of the above cases the independent producers supply high grade limestone or make-up lime to the captive plants.

Isacor, from its 60,000 tpm Pretoria plant, currently produces some 44,000 tpm of special and metallurgical grade dolime. Grades for refractory products include sizes of -40 +20 mm and compositions of 30% CaO, 21% MgO, and a maximum of 0.8% SiO<sub>2</sub> plus insolubles. Other metallurgical grades range from -6 +1 mm to -40 +20 mm in size and allow up to 2.5% SiO<sub>2</sub> plus insolubles.

A feature of the South African lime industry is the vast distances over which the products have to be transported. The high grade calcitic limestone deposits in South Africa are massive in size but occur in a defined area in approximately the middle of the country. Transport often represents 40% (if coal transport is included) of the price of the product. The markets are scattered in the major metropolitan areas with a concentration in the Witwatersrand complex. The average distance lime products travel is 600 km and coal is transported some 700 km to the major producing plants. This feature explains the relatively small number, but large size, of burnt lime plants.



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**South African burnt lime plants and products, 1988**

Company	Plants	Annual lime capacity ('000)	Product Range			
			Unslaked	Hydrate	Dolomitic hydrate	Limestone
PPC Lime Ltd	Lime Acres	2,180	*	*		*
	Marble Hall	25		*		*
Union Lime Co. Ltd	Ouplaas	1,100	*	*		*
	Ulco	100	*	*		*
	Umzimkulu	11			*	*
Cape Lime Co. Ltd	Langvlei	40			*	

Source: PPC Lime Ltd

**South African burnt lime consumption by end use, 1988**

Product	Gold and uranium	Iron and steel	Calcium carbide	Soil stabilization	Chemical and fertilizers	Other
Reactive u/s		*				
Unslaked	*	*	*	*	*	
Hydrate				*	*	
Limestone		*			*	*
Approx. market share	0.44	0.22	0.13	0.07	0.05	0.09

Source: PPC Lime Ltd

In South Africa, huge amounts of lime are used to recover uranium from the slimes left after the processing of gold. The lime industry's receptiveness to trends in the uranium market was reflected in the 1982 decline in lime consumption owing to the international cut-back in uranium oxide demand. Shortly after this, a clampdown on the local economy, to arrest high inflation rates, constrained market growth in other sectors as well. Since then, the lime industry has had a virtually flat sales pattern and presently has around 30% over-capacity.

➤ **Netherlands**

B.V. Nekami Kalk is the Netherlands sole independent producer of burnt lime products. The company has a joint venture with Belgian lime producer Carmeuse, called Sté Cooperative des Carrières Andenne-Seilles. The name pertains to the exploitation of the limestone deposit at Seilles-Andenne. Nekami's share of burnt lime production from this quarry (crude annual output 1m. tonnes) is in part sold directly to Benelux, while the remainder is shipped to Nekami's hydrating plant in Gouda for further processing.

The Gouda plant, in the western Netherlands, produces some 40,000 tonnes of calcium hydrate for chemical and environmental uses, and an additional 40,000 tonnes of mixed products for the building/construction market. Products for this market include ready-mixed mortar products composed of lime, cement, and sand. Nekami mainstream products include finely ground burnt lime, high quality hydrated lime, masonry lime, hydraulic lime, and bulk mortars in silos. Nekami is also involved in developing new products for application in water treatment, flue gas cleaning, and flow mortars for screeds in the building industry.



## HATCH

The lime and dolime market in the Netherlands is characterized by relatively strong competition between a number of Belgian and West German producers. Growth in the environmental market in Western Europe has been offset to a large extent by the reduction in sales to the steel market. Lime product prices have remained stable over the last few years and have in a number of cases even decreased. Generally speaking, the Netherlands' lime market conditions appear rather flat.

### ► Japan

Annual Japanese lime production has gently fluctuated within the 8-9m. tonnes range since early nineties. In that year, production amounted to 9.5m. tpa (quicklime 7.7m. tonnes, hydrated lime 1.7m. tonnes) with 53% for iron and steel manufacture, 26% for chemical manufacture, 10% for construction and agriculture, and 11% for other uses. These market conditions remained much the same through eighties before declining in nineties. The effect of this fall in steel production perhaps indicates the sensitivity of the lime industry's dependence on the iron and steel industry. The following table shows the top ten lime producers of Japan in early nineties, each of which has a capacity of at least 100,000 tpa.

#### Top ten Japanese lime producers

Nihon Sekai Lime Co. Ltd  
Kawai Lime Co. Ltd.  
Okutama Kogyo Co. Ltd.  
Yoshizawa Lime Industries Co. Ltd.  
Ube Material Industries Company Ltd  
Yabashi Lime Co. Ltd.  
Jeda Lime Co. Ltd.  
Chichibu Lime Industries Co. Ltd.  
Ryoko Lime Co. Ltd.  
Maruei Lime Co. Ltd.  
Irimagiri Lime Co. Ltd.

Source: Japan Lime Associates

With the move to produce higher performance steels, particular attention has been drawn to significantly reducing phosphorus content to 0.005% P. At Nippon Steel Corp., a mixture of 18 kg per tonne powdered lime, 28 kg per tonne of scale, 2-5 kg per tonne fluorspar, and 2.5 kg per tonne calcium chloride has been used to reduce hot metal phosphorus levels to <0.005%.

Other Japanese companies have developed similar procedures. Kobe Steel has used 24 kg per tonne of powdered lime/scale/fluorspar mixtures to reduce phosphorus content to 0.008% and sulphur content to 0.006%. Kawasaki Steel has utilized the bottom blown vessels at its Chiba works to effect simultaneous sulphur and phosphorus removal by injecting a mixture of 31% CaO, 59% iron ore, and 10% spar through the tuyeres at the same time as using a top slag addition of 73% CaO and 27% spar. A total addition rate of 20 kg per tonne lime, 3 kg per tonne spar, and 6 Nm<sup>3</sup> per tonne oxygen is required to produce the conditions necessary to reduce sulphur and phosphorus to the 0.1% level.



**HATCH**

Concerning use of lime in FGD systems, Japan offers little potential for this market. Historically, Japan has been a leader in implementing stringent controls of air pollution. All Japanese utility FGD plants use the wet lime, or more commonly wet limestone, process. Most processes use the wet limestone/gypsum method, and since Japan has no natural resources of gypsum, the gypsum by-product from this process is rather useful. Spray dry-type dry lime scrubbing processes are not desirable in Japan since legislation requires over 95% SO<sub>2</sub> removal and little land space is available for by-product disposal.

Stringent restrictions in Japan upon the ways of handling explosives and reducing environmental pollution, such as noise and vibration, led to the development of non-explosive agents in 1979. The non-explosive agent is essentially composed of burnt lime coated with self-hardening materials such as calcium silicate, calcium ferrate, or calcium sulphate, which is then ground to a powder. Together with an appropriate quantity of water, the mixture is poured into previously drilled holes of the rock or concrete to be demolished. It hardens and expands, and over time, expansive stresses reach more than 30 MN/m<sup>3</sup>, and thus break up the rock.

Recently, lime producer Calceed Company Ltd., with lime plants in Chiba and Yamaguchi Prefectures, merged with magnesia producer Ube Chemical Industries Company Ltd. To form a new company called Ube Material Industries Company Ltd. Ube Chemical was a major customer of Calceed and its parent company, Ube Industries Ltd., was a major shareholder in Calceed. The merger is expected to produce efficiencies and benefits in research and development, planning, production, sales and marketing, especially when dealing with steel customers that consume lime and magnesia products (Industrial Minerals, 6).

► **Spain**

Spanish lime and dolime production, which was estimated to be 1.3m. short tons in early nineties, is dominated by the Fidel Azcarbide Group. The group consists of four companies - Dolomitas del Norte SA, Andaluza de Cales, Cales de la Plana, and Caleras de Legorreta (see accompanying table for operations).

**Spanish lime producers and their products (tpa)**

Fidel Azcarbide		QL 200,000
Dolomitas del Norte		QL 2000,000
		DBL 70,000
	(Montehano plant	DBL 30,000)
	(Carranza plant	DBL 20,000)
Andaluza de Cales		QL 100,000
		HL 35,000
Cales de la Plana		QL/DL 70,000
Caleras de Legorreta		HL 32,000
Productos Dolomíticos SA		
	(Revilla	DBL 60,000)
		DL 24,000)
	(Aviles	DBL 75,000)
		DL 24,000)
	(Palleja	DBL 25,000)
		DL 12,000)

QL quicklime; DL dolomite; DBL dead burnt dolomite; HL hydrated lime

**HATCH**

The primary consuming industry is steelmaking, after which burnt lime products go into the chemical, paper, fertilizer, construction, road, environmental, and water treatment markets. Product particle size is usually in the range of 3-30 mm, with special grades ranging from 1.5-3.5 mm to 0-0.2 mm.

The future of the Spanish lime industry is uncertain at present with traditional markets such as steelmaking, consuming less, and requiring greater production of better quality end products. New markets for lime, FGD, and other environmental applications have yet to take off.

➤ **Portugal**

A significant portion of the lime/dolime industry in Portugal is still performed at locally based minor operations with low capacity traditional furnaces intended to serve consumers in the local area. A great number of producers, with greater size operations and modern furnaces, obtain their lime through captive production and do not, in general, disclose production data. As such, it becomes rather difficult to obtain an overall picture of the industry and markets.

Essentially, the smaller lime producers deliver their products to lime consumers whose production, if any, is not enough to cover their requirements. Lime is consumed in iron and steel, pulp, basic metallurgy, mining and ore dressing, water and effluent treatment, chemicals and fibers, tanning leather, textiles, and construction.

Of the larger producers, since the shut-down of the Ytong Portugesa furnace, Quimigal - Quimica de Portugal E.P. is the only one remaining in the lime market. With an annual capacity of 30,000 tonnes, Quimigal's sales in 1987 had the distribution shown in the table.

Metallurgical	37%
Chemicals	46%
Pulp and paper	17%
Current prices	£30-£40 per tonne

The Portuguese lime industry practically takes no part in foreign trade in lime or dolime. In 1986, lime production was estimated to be in the region of 220,000 short tons, and there exists a significant amount of over-capacity and no major increase in the market is expected. A certain rise in lime demand may be considered in the future regarding environmental utilization. Any new production is expected to include that of captive producers.

➤ **Brazil**

Reserves of limestone for the manufacture of lime in Brazil amount to some 6,000m. tonnes. In early nineties, Brazilian production had reached 4.9m. tonnes. The main producing areas were:

Estado de Minas Gerias	42.0%
Sao Paulo	20.0%
Parana	15.0%
Bahia	2.8%
Pernambuco	2.0%
Sergipe	1.9%



**HATCH**

Of total Brazilian production, quicklime represents around 60%. After cement, lime manufacture is the second largest consumer of limestone.

At present, reports indicate that markets, particularly for dolomitic lime, are increasing in the steel, construction, and agricultural sectors, while refractory use is more or less stable. The Brazilian lime industry apparently expects a promising future, with abundant supplies of limestone and dolomite, low cost production, and a wide range of applications. Future markets include FGD and soil stabilization.

➤ **West Germany**

According to USBM statistics, West Germany is possibly the fourth largest lime producer in the world with some 7.8m. short tons produced in early nineties. The four major producers in 1988 were Rheinische Kalksteinwerke GmbH (RKW), Rheinisch-Westfälische Kalkwerke AG (RWK), Schaefer Kalk, and Dolomitwerke GmbH Wulfrath, an associate of RKW (see accompanying table).

**West German lime producers and products, (tonnes per annum)**

RWK	capacity	BL	2.1m.
	output	BL	1.5m.
RWK	output	BL	1.2m.
	Dolomitwerke GmbH	SD	70,000
Schaefer Kalk	output	SBD	220,000
	capacity	BL	100,000
		HL	160,000

BL burnt lime; HL hydrated lime; SD sintered dolomite; SBD soft burned dolomite

Market destinations for these products are confined mostly to Europe, and domestically RWK is the market leader with around 26% of the lime market. Sales of burnt lime during 1987 are summarized in the accompanying table and show that around 50% of lime sales are consumed in the iron and steel industry. The future holds expected increases in markets such as FGD, industrial waste and sewage treatment, and domestic water treatment.

**West German burnt lime sales by end markets, 1988  
 ('000s tonnes)**

Iron and steel	1,980
Chemicals	690
Environmental	670
Construction	1,050
Building products	460
Agriculture	340
Exports	410
Total	5,600

Source: RWK



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### ► Mexico

In the early nineties, Mexico produced some 4.4m. short tons of lime products. Producers involved in the industry include Industrias Hersan SA de CV, Industrias Penoles SA de CV, Penuela y Contadero SA, Regio Cal SA de CV, and Yeso El Tigre SA.

Regio Cal produces dolime from two plants, Villa de Garcia - 36,000 tpa dead burnt and hydrate for steel refractories (80%) and other refractories (20%), and Monterrey - calcined and hydrated, 170,000 tonnes and 130,000 tonnes respectively.

Hydrated products are consumed by the sugar cane industry which represents some 10% of the total domestic lime market and is characterized by seasonal consumption between the end of November and the end of April. Some sugar plants use high calcium lime, but if there locations are favorable dolime is used. Required specifications are tightening for the steel industry which consumes refractory grade dolime. Regio Cal hopes to begin production of dead burned dolomite for high quality sintering grades during May/June this year. The Mexican refractory industry, which is currently working at half capacity, is showing signs of recovery.

A small but growing market for dolime has been in the stabilization of highways. Industrias Penoles SA de CV produces both lime and dolime. All dolime produced from the plant at Quimica Del Rey SA de CV, with a capacity of 170,000 tpa, is consumed in the company's internal MgO manufacturing process. Likewise, most of Penoles' lime, 140,000 tpa capacity, is consumed in the MgO process. Lime production is currently at 90% and other consumers use the lime for chemicals, acid neutralization, and PCC production.

### ► France

The French materials group, Lafarge SA, acquired the British construction materials company Redland PLC. The takeover included aggregate and lime operations in North America, including the lime plants of Redland Ohio Co., and Redland Stone Products Co. in Texas (Financial Times, UK aggregates, readymix shares up on bid hopes after Lafarge wins Redland, accessed January 22, 1998, at URL: <http://www.info.FT.com/news/company/company-261197-72.htm>).

The French burnt lime industry is supplied by subsidiaries of the Belgium-based Lhoist Group - SA des Carrieres et Fours a Chaux de Dugny (at Dugny, eastern France, 700,000 tpa capacity lime). SA des Chaux et Dolomies du Bolonnais (at Rety, northern France, 650,000 tpa capacity lime and soft burned dolomite, at Boran, Paris area, 110,000 tpa capacity hydrated lime), and SA des Fours a Chaux de l'Aisne (northern France). Others producers include La Dolime Francaise which has two plants at Neau and Voisey producing dolomitic lime calcined and dead burnt (for construction) and Ets Bocahaut SA which produces 120,000 tpa quicklime. Sté Siche, located in Gannet, produces some 40,000 tpa burnt lime, 50% for agriculture, 25% for road stabilization, and 25% for water treatment.

There is a drop in usage found in agriculture, although the utilization of lime in this sector depends largely on the yearly environmental conditions, i.e., whether conditions are more or less suitable for spreading nutrients. Other sectors experiencing a decline in lime demand include the area of water treatment, minerals, and non-ferrous metals. Exports of burnt lime products remained virtually the same in over the years at around 300,000 tonnes. The outlook for growing markets shows some potential in the building industry particularly in the manufacture of building products as well as road construction. The growing market for ground stabilization is expected to be influenced by the planned development of the north TGV rail

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network. Other developments are hoped for in the environmental air and gas purification market with continued research into lime use in water treatment, road construction, and agriculture.

**➤ Italy**

Calcestruzzi Calo Anonio, Manduria, installed a Cimprogetti Cim-Reversy twin shaft kiln at its plant in southern Italy. The project cost \$10 million and was scheduled for completion at year end 1997. Fornaci Crovato SpA, a member of the Carmeuse Group, ordered a Maerz parallel flow regenerative two-shaft kiln with a capacity of 200 tons per day (220 short tons per day). Calce Mori Srl, a member of the Dolomite Colombo Group, installed a 300 ton per day (330 short ton per day) Maerz shaft kiln at its Palagiano (Taranto) plant. Sider Calce SpA, also a member of the Dolomite Colombo Group, announced plans to install a 250 ton per day (275 short ton per day) Maerz shaft kiln at its Campiglia Marittima (Livorno) plant (World Cement, 1997b).

**➤ Turkey**

Carmeuse SA, the Belgian lime and limestone group with operations in Europe and North America, announced a large investment program in Turkish lime and limestone operations. Carmeuse plans to invest in joint ventures with Aster Kimtas AS and the Isiklar Group of companies. Carmeuse, directly or indirectly, owns 50% of each of these firms which have a combined lime production capacity of 1,450,000 tons per year (1,600,000 short tons per year). Isiklar operates limestone and lime operations at Bartin, Kirsehir, and Silviri; and Aster Kimtas operates facilities at Bergama, Urla, Mugla, and Isparta (Industrial Minerals, 1997a). (See table 5.)

**6.5 Current Research and Technology**

Southwest Research Institute, a non-profit research and development organization located in San Antonio, TX, has developed a lime-based paint designed to exploit lime's biocidal properties. The problem was that calcium hydroxide is incompatible with every known latex compound, resin and plastic solutions, solvent-based paints and coatings, and plastic and elastic film-forming materials. To be effective the lime has to be exposed and active, but all of the 260 materials tested were either damaged or destroyed by the lime or encapsulated the lime in a plastic or elastic film.

The researchers finally found three classes of polymers that are not used in conventional paints. These polymers tolerated all levels of lime indefinitely, provided good adhesion to surfaces, and allowed optimum volumes of various additives (pigments, fillers, surfactants, etc.) to be incorporated. Importantly, they allowed the lime to be active, durable, and effective in killing multiple varieties of viruses, bacteria, fungi, and mildew. This lime-based coating has successfully undergone abrasion and weatherability tests, actual exposures to New York environments and Texas weather, and biocidal tests. The potential applications of this non-toxic coating include floors and walls of nursing homes, hospitals, day-care centers, nurseries, restaurants, and kitchens. Other applications include meat lockers, pantries, air ducts, and any other surface where mold grows and mildew discolors (Paint and Coatings Industry, 1997). Dravo Lime has introduced a specialized flue gas technology called Sorbalit to North America.



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The technology is patented by Märker Umwelttechnik of Germany, and combines the neutralization characteristics of lime with surface-activated substances such as activated carbon, lignite or coke to control acid gas, mercury, and dioxin emissions from a variety of combustion applications. The sorbent is custom formulated with either quicklime (Sorbalime) or hydrated lime (Sorbalit) and includes from 2% to 65% carbon. The technology is versatile enough to be used with a wide variety of wet and semidry scrubbers, as well as duct injection systems (Dravo Lime Co., n.d.).

Canadian firm, Ateba Mines Inc., has developed a patented process to recover phosphate fines from the liquid clay tailings (slimes) that are removed by hydrocyclones during the beneficiation of phosphate rock. These slimes are currently disposed of in ponds and, because these slimes form colloidal suspensions, it takes years for solids to settle out. Ateba's process involves injecting a chemical agent into the slime pond to liquefy the clay in which the phosphate fines are suspended, and the fines can then be recovered using hydrocyclones. The resulting liquid-clay waste stream can then be treated with lime to form solid tailings more suitable for disposal. The company was expecting to sign a deal with a Florida phosphate producer to set up a pilot plant (North American Mineral News, 1997b). If this process proves successful and is widely adopted by Florida phosphate producers, there may be a significant increase in lime demand in Florida.

### 6.6 Future Outlook (US and Others)

Lime has dozens of end uses in the chemical, industrial, and construction industries, but 70% is consumed in seven clearly defined markets: drinking water treatment, FGD, iron and steel, precipitated calcium carbonate, pulp and paper, ore concentration in the mining industry, and soil stabilization. The forces behind these markets include the health of the economy, metals prices, extreme weather, and Federal funding levels. Steelmaking remains the largest single end use for lime. The serious economic problems affecting Japan, Russia, Southeast Asia, and the developing countries may eventually have an adverse affect on the U.S. economy. This would affect US steel production because of lower demand or because of increased imports of cheap steel. Steel production is expected to increase in 1998 and 1999, but the extended outlook is less clear. In the near term, demand for lime by the steel industry will follow the trends in domestic steel production, although in the long term, lime consumption by the steel industry may flatten out or decrease because of industry changes in raw materials and flux usage. The latter includes greater use of flux pellets and hot metal desulfurization.

The FGD market decreased slightly in 1997 because of a mild winter and summer in the Midwest, but despite this downturn in consumption the future continues to look promising for this market. Major FGD lime suppliers such as Dravo Lime are counting on the conversion of utilities in the Ohio River Valley to lime scrubbing from competing reagents, and feel that shipments to current customers could increase if the utilities decide to operate their scrubbers at higher levels prompted by an increase in the sulfur content of their fuel or a decision to overscrub to earn additional emission allowances. Phase II of the Clean Air Act Amendments, which takes effect January 1, 2000, and regulates small utility generating units, will probably provide an additional boost to lime sales after 1999. Lime scrubbers display favorable efficiencies and economics for these small units.



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Regulations covering small municipal incinerators and waste to energy incinerators also favor the use of lime scrubbers. Quantifying the increased demand generated by Phase II and other emissions regulations is difficult (note the unexpected dip in demand in 1997), but some industry projections have forecast FGD demand at 5 million tons (5.5 million short tons) by 2002. Major FGD lime producers are investing in research and development to lower the capital and operating costs associated with lime scrubbing and to produce salable by-products. The goal of such research ultimately is to provide environmentally sound and economic technologies designed to attract customers from power plants currently utilizing limestone scrubbers or low-sulfur coal.

Soil stabilization sales remained strong and topped the 1 million ton mark for the second year in a row. The soil stabilization market is affected by the level of funding for highway construction, the weather, and competition from products like cement. The use of lime in asphalt paving increased dramatically by 73% in 1997 after the decrease of 35% in 1996. This only brings sales up to the same level they were in 1994, and suggests the large decrease reported in 1996 may have been a reporting error. Stabilization and asphalt markets are expected to be boosted significantly by passage of new transportation legislation (Transportation Equity Act for the 21st Century). This legislation budgets \$167 billion over 6 years for highway construction which is a 44% increase compared with the previous 6 years. Healthy increases in lime sales for stabilization and asphalt are expected during this period. The legislation was not signed into law until the summer of 1998, so evidence of such increases probably won't show up until 1999.

Demand in lime's traditional pulp and paper market rebounded somewhat in 1997, but no long-term growth is expected in this market. Current environmental controls make it expeditious for pulp mills to regenerate as much lime from their carbonate sludge as possible which lessens the need to purchase make-up lime. The PCC market increased by 12% in 1997, and will probably continue to grow as PCC attempts to expand into the groundwood paper and paper coating markets. Anticipated growth in the PCC market is expected to be particularly strong in the Southeastern United States. Overall, commercial lime sales are expected to grow at about 3% per year over the next several years. Barring any greenhouse gas emissions legislation, the only major market force on the horizon is Phase II of the Clean Air Act Amendments, which may boost FGD sales after the year 2000.

The future outlook for the US lime industry lies in a resurrected, albeit smaller, iron and steel industry, and in new emerging markets in stabilization (including use in asphalt), and air pollution toxic waste control.

FGD processes, and more importantly consideration of lime versus limestone as a reagent, have been discussed in another section. It has been estimated that US lime demand for FGD could range from 3.7-9.9m. short tons. Already this market sector is reported to be at its maximum usage of lime. Some 1m. tpa of Dravo's thiosorbic quicklime products is consumed in FGD. However, important influencing factors are the continued use of high-sulphur eastern US coal rather than switching to low-sulphur western US Coal and favorable economics for using lime rather than limestone. Reasons preventing widespread shipment of western coal to the east include current rail transportation costs and lobbying by the United Mine Workers Union to make sure eastern coal is still used despite any sulphur-content restrictions. Limestone appears to be the most popular desulphurizing agent, mainly due to its widespread availability and cost competitiveness. Wet scrubbing has been found to be more effective for the high sulphur coals, thus favoring a limestone (or to a lesser extent lime) sludge to be used as an absorbent.



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Although there exists at present no widespread potential for lime in FGD systems, there is an outlet in this market sector with local municipal incinerators which are subject to federal order to utilize scrubbing systems. In these cases, lime is effective as a more reactive scrubbing reagent (usually in the form of a slurry) than limestone and units served are typically in the order of only 1-5-mW.

Soil stabilization is catching on with growing recognition of the successful use of lime in predominantly clay-poor areas, which previously had not been selected as favorable sites for this practice.

Asphalt stabilization, in particular, holds growing potential for lime consumption, albeit with additions of 1-2% hydrated lime being the norm. As well as its usefulness as an anti-stripping agent, lime enhances the lifetime of asphalt through prevention of cracking. In most cases, the use of Portland cement as an alternative material is not really suitable, and would only provide use as a filler.

**7. NW TASMANIAN CARBONATE ORE**

**7.1 NW Tasmanian Carbonate Ore Source and Composition**

Mineral Holdings Australia Pty. Limited (MHA) has retention licenses RL.9710 (EL.33/90) (a dolomite source) at Togari and east of Redpa RL.9709 (EL31/90) (a dolomite, tertiary limestone and magnesium rich limestone source), at Carbonate hills. The dolomite and dolomitic limestone in all of the leases is considered to be the same stratigraphic sequence and is described as Smithton Dolomite. The carbonates of dolomite, magnesia rich limestone, and limestone in this area are all considered to be marbleized and therefore excellent for processing and transportation as ore with low dust.

Licenses/Leases/Permits

MHA Tenements	Area	Name	Resource	Area, km <sup>2</sup>
Retention License 9709 (Exploration License 31/90)	NW Tasmanian	Redpa Carbonate Hill	Limestone, Dolomite Dolomitic Limestone	6
Retention License 9710 (Exploration License 33/90)	NW Tasmanian	Togari (BS)	Dolomite	9

The dolomite at Redpa is over 1000m thick and covers 1 km<sup>2</sup> area, outcropping sporadically through the area. It is considered to be a potential for producing 2 million tonne per meter depth in the license and the depth of mining is considered to be limited by the practicalities of mining and economics. In the eastern portion of the license there is an additional source for Pre-Cambrian rock type dolomitic limestone or magnesium rich limestone. It has been reported that this has a potential of producing in excess of 100 million tons of magnesium rich limestone or dolomitic limestone. There is also a reported source for marbleized tertiary limestone with excellent furnaceability with minimum decrepitation. This deposit is estimated to be in the area of 2 kilometers in length and 1/2 kilometers in width. The reported average composition of the sample taken from this area is given below.



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**REDPA DOLOMITE, LIMESTONE AND DOLOMITIC-LIMESTONE ANALYSIS**  
 (weight percentage)  
 (All numbers are average % composition)

	Limestone	Mag-rich Limestone (Dolomitic Limestone)	Dolomite
SiO <sub>2</sub>	0.66	0.95	0.40
TiO <sub>2</sub>	0.17	0.04	0.013
Al <sub>2</sub> O <sub>3</sub>	0.28	0.21	0.31
Fe <sub>2</sub> O <sub>3</sub>	0.61	0.09	0.23
MnO	0.03	0.01	0.006
MgO	0.90	13.95	21.40
CaO	54.02	38.31	30.41
Na <sub>2</sub> O	<0.01	0.23	0.12
K <sub>2</sub> O	<0.01	0.07	-
P <sub>2</sub> O <sub>5</sub>	0.096	0.037	-
SO <sub>3</sub>	0.59	0.51	-
CuO	-	-	0.0005
Cr <sub>2</sub> O <sub>3</sub>	-	-	0.0009
L.O.I	45.11	45.33	46.97

Dolomite at the Togari area outcrops prominently and is considered to be of very high quality and low in silica and other impurities. This area covers around 9 square kilometers and has a very large potential resource to develop as open cuts operation. The consulting geologist hired by MHA has estimated the total amount of recoverable dolomite is around 1600 million tons (assumed only 20m depth). The average composition is similar to that of Redpa dolomite. The average composition of the samples analyzed is given below.

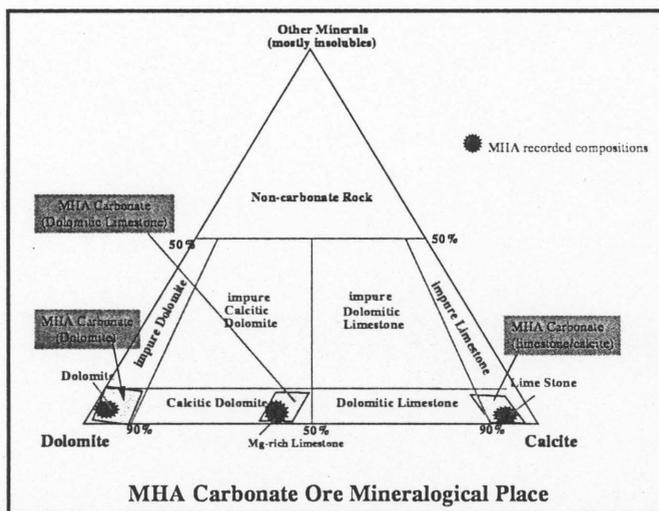
**TOGARI DOLOMITE ANALYSIS**  
 (weight percentage)  
 (All numbers are average % composition)

SiO <sub>2</sub>	0.44
TiO <sub>2</sub>	0.01
Al <sub>2</sub> O <sub>3</sub>	0.54
Fe <sub>2</sub> O <sub>3</sub>	0.24
MnO	0.005
MgO	19.62
CaO	32.86
Na <sub>2</sub> O	0.08
K <sub>2</sub> O	-
P <sub>2</sub> O <sub>5</sub>	--
SO <sub>3</sub>	-
L.O.I	46.16

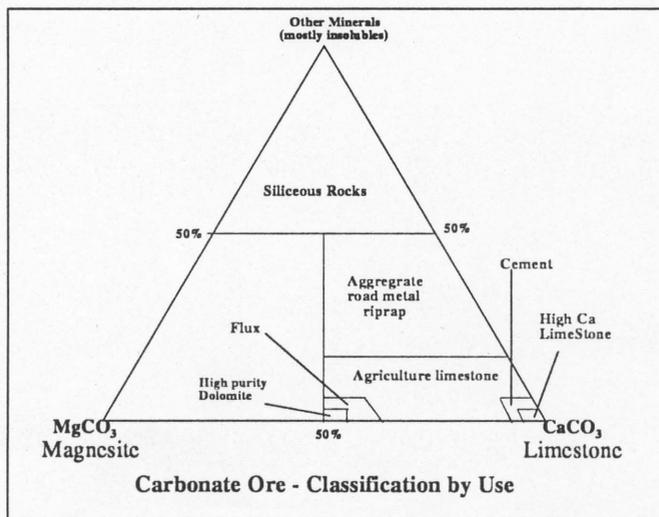


### HATCH

The above dolomite, limestone and dolomitic limestone are placed on the hypothetical mineralogical classification triangle chart given below. Pure limestone and dolomite are the two corners of the triangle. The blocked area indicates a possible variation in the composition and the rounded stars indicate the measured average composition of the sample taken at different locations.



The following diagram gives an approximate main cost effective use of the MHA carbonate ore. However, composition of the ore can be altered to apply in other applications also. For example, limestone or dolomite of pure quality can be used in agriculture, construction, and road pavement application.



## 7.2 Potential Applications for NW Tasmanian Carbonate Ore

The NW Tasmanian carbonates of dolomite, magnesia enriched limestone and limestone are all assumed to be marbleized and crypto-crystalline in nature and therefore excellent for furnacing or processing further or transportation as ore with low dust. Samples tested by various laboratories and companies and the result presented to Hatch have proved that they are of high grade, with low impurities, and with excellent furnaceability. Hence, this material is suitable for most of the traditional carbonates applications discussed earlier in the section. Let us re-evaluate it separately here.



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The uses of NW Tasmanian carbonate ores (dolomite, dolomitic limestone and limestone) can be divided into three general classifications. They are:

- **NW Tasmanian Carbonate Ore Direct Application:** The carbonate material is applied as a physical form with minimum crushing and screening. Main applications in this category are construction aggregates, in agricultural and soil remediation, in environmental (flue gas recovery), as fillers, in cement, in metallurgical (as a flux), in glass and in chemical uses.
- **NW Tasmanian Carbonate Ore Calcined (Lime) Application:** The carbonate ore is calcined at various elevated temperature and resulted material is used for various application. The main uses in this category are as quicklime, lime or dolime (based on it derived), in chemical industries, in metallurgical (as a flux, as a chemical or furnace lining protector), in agricultural, in cement, in refractories (silicate bricks and others), and magnesia foams.
- **Chemical from NW Tasmanian Carbonate:** The material is processed further chemically to obtain chemicals for various other chemical and metallurgical applications. This is mainly applied to dolomite or magnesian limestone. The main chemicals from ores are Mg metal, MgO, Mg-hydroxide, Mg-carbonate and other magnesia compounds.

### 7.2.1 NW Carbonate Ores Direct Applications

#### ➤ Road Aggregate and Construction Area

One of the largest applications of NW carbonate ore may be in the aggregate and construction area. It is well documented that approximately 60% of all the dolomite and 40% of all the limestone produced in the world are used as aggregate and construction purposes. I expect this may be the same situation in Australia. That means Australia employs around 6 million tons of dolomite and 4 million tons of limestone as aggregate and construction material excluding the use in cement. The main requirements for materials for road aggregates are mainly physical characteristics and particle size distribution, the specification of which was given earlier in the discussion. NW Tasmanian carbonates (dolomite, dolomitic limestone and limestone) are marbleized and crypto-crystalline and are excellent materials for this application. The marbleized materials generally have good AAV, ACV, and AIV numbers with a good flakiness index. The tests have shown that these carbonates are very small amounts of fines (much less than the 10% value for aggregate application). The major question in the application is the economics. The market is limited to the area in the neighborhood of the mine because this is a lower selling market area and transport cost is the major factor. In the US, the selling price in 1998 for both limestone and dolomite was around US\$5.60 f.o.b. The transport costs and proximity of consumers are the major factors which will determine the market.

Other areas where all of these three types of NW Tasmanian carbonate ores find some application are as an asphalt filler, concrete, and railway ballast. Asphalt filler is controlled by a particle size and other hard physical characteristics. Hence, carbonate ore is an excellent material for asphalt filler, especially beneficiated limestone and dolomite fines. NW Tasmanian carbonate ore is also dense, hard material with low porosity and free from clay, mica, shale or other platy or laminated particles and can find direct application in concrete and railway ballast. Again, this market is a low selling and low demand area and proximity of the customer is an important factor in its application.



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### ➤ Agriculture and Fertilizer

The agriculture market world commonly represents dolomite's second largest and limestone's fourth largest consumer. The main requirement for this application is the particle size which should be in the range of 1.25 - 0.18 microns. The function of the carbonate ore is to reduce soil acidity and supply calcium and magnesium nutrients to the soil. NW Tasmanian carbonate ore can be effectively employed in agriculture/fertilizer applications. France and the US are two of the largest consumers of these materials for agriculture application. This material fetches a slightly higher price than the road aggregates after some milling and processing (before marketing).

NW Tasmanian limestone contains a very low amount of impurity (minimum amount of MgO, silica, alumina, iron and other toxic elements), and greater than 96% calcium carbonate. It may be an excellent source for animal and bird food additives. The NW Tasmanian dolomite fines with an excellent density and chemical purity, from the beneficiation steps can be marketed to fertilizer industries as a filler material to add weight, reduce caking and improve the physical condition of the mixture, and also to adjust the blend to the desired ratios of fertilizing elements. Again, price is dependent on individual company's demands and requirements. Other dolomite applications may be as barn stone, poultry grit, and mineral food with limited market potential.

### ➤ Environmental

Every year the Australian electric generating plants or utility companies produce near 1 million tons of sulphur by burning coal. The resultant large emission of sulphur is precipitated out as acid rain. Hence, there is a large demand for a high quality limestone to use in fluid gas desulphurization (FGD) plants and demand continues to rise over the years. Limestone is by far the most popular desulphurizing agent mainly due to its availability, cost, and technical efficiency. NW Tasmanian tertiary limestone with greater than 90% CaCO<sub>3</sub> content, less than 5% MgO content and less than 5% acid insolubles may be best suited for this application. The other requirement yet to be proven for this limestone is its microporosity and surface area. Particle size generally used for this application is 325 mesh. Dolomite can also be used in FGD systems with consumer consent with certain restrictions. Estimating the exact tonnage of limestone required for FGD units is particularly difficult because of the secrecy involved with the companies. The requirement in Australia may be more than a million ton of limestone, dolomite, and lime combined.

### ➤ Metallurgical

Marbleized limestone has always been the major flux material for the metallurgical industries that produce slag especially pig iron industries. However, in recent years it was recognized that partial amount substitutions of pure dolomitic lime or dolomite for high calcium limestone flux resulted in greater refractory life. Specifications for the use of dolomite and limestone as a flux vary with the steelmaking process, kind of ore processed, and final use of slag.

Australia imports millions of tons of flux materials from Canada and China, especially dolomitic materials. Since NW Tasmanian marbleized dolomite possesses excellent flux properties with its negligible amount of fines and sulphur content and low silica, alumina, and phosphorous content, the only questionable aspect in the NW Tasmanian limestone and dolomitic limestone is the borderline amount of sulphur content. However, a proper blend of dolomite and limestone can overcome it. The demand is big and it exceeds several million tonnes per year which can be estimated with metal manufacturing numbers given in the Appendix. Australia annually produces around 8 million tons of pig iron, around 9 million tons of steel crude, and over 5



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thousand tons of semi-manufactured metal. Other markets for the flux may be Southeast Asia, especially Japan, Korea, and Taiwan.

### ➤ Cement

Australia annually produces over 6.5 million tons of hydraulic cement and limestone is one of the important components. An important parameter required for cement application is the lime saturation factor which is met by the NW Tasmanian limestone. With low fluorine, sulphur and phosphorous content, it may be a good material for cement application. Dolomite has been used for a quick drying material to mend cracks in concrete roadways. Dolomite is also used to manufacture oxy-chloride and oxy-sulphate cement. Specifications for dolomite is dependent on its intended application and the customer.

### ➤ Glass

The carbonate rock's prime function is in the introduction of calcium oxide as the major fluxing material into soda-lime-silica batches. Limestone is an important component in glass manufacture because of its fluxing action on the silica sand to form a chemically fused calcium silicate glass phase. The Australian requirement of this flux is over 2 million tons. NW Tasmanian limestone may not meet the specification for a colorless glass but certainly meets the specification for flat glass, container glass, float glass, and fiberglass. Again, application requirements will be dependent on the individual consumer. The functions of the dolomite in the glass batch are that it can reduce the tendency for devitrification, thereby reducing losses, inhibit chemical attack by atmospheric gasses or moisture, improve workability through lowering the setting rate, and in colored glass through smoothing out viscosity differences at varying temperatures, increases the fracture resistance of the glass caused by thermal shock, and contributes additional fluxing action. The dolomite is only used as a partial supplement to limestone. NW Tasmanian dolomite and magnesium rich limestone both meet the specifications for glass.

### ➤ Chemical and Industrial

There are different possible applications for NW Tasmanian dolomite, limestone, and dolomitic limestone covered by the common term "whitings". Due to the vast range of applications in the whiteners business grades tend to be of a more customized nature. The specification for this application was given earlier. Other applications that are suitable for the Tasmanian carbonate rocks may be as a paint filler and putty application because of its low absorption properties and dense particles with good flakiness index. However, volume required for these applications are very small.

### ➤ Coal Dust Blend

Australia is the world's sixth largest producer of coal in the world. In 1997, Australia produced more than 215 million tons of coal from over 60 mines. NW Tasmanian limestone and dolomite fines may be excellent material for a coal dust blend. Limestone and dolomitic material is spread among the mine galleries and roadways to form an intimate mixture with the coal dust so when the particles are thrown up during the hot blast of an explosion, the heat capacity properties of the coal are drastically reduced and combustion thwarted. A typical US and UK specification is given earlier in the text.



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## 7.2.2 NW Carbonate Ores Calcined (Lime) Applications

The term "lime" is a general term and covers all the calcined products from high purity calcitic or dolomitic limestone (quicklime, dolomitic quicklime, hydrates and dead or hard burnt dolomite). The major areas of applications are in the chemical, metallurgical and environmental, and minor areas of applications are in construction, refractory, and agriculture. This market commands a higher selling price compared to uncalcined material and with flexibility in volume control, handling and marketing. Since carbon dioxide emission (greenhouse gas) is not a problem for Australia under the international agreement, it may be advantageous to market the NW Tasmanian carbonate as a calcined product.

Calcination is a function of both temperature and carbon dioxide pressure. It is also strongly time variant depending on the type of the rock. Literature suggests that marbleized crypto-crystalline pure carbonate rocks produce porous, reactive lime under mild temperature calcination conditions and a denser, less porous lime under hard or dead burnt condition. It is expected that NW Tasmanian carbonate rocks should produce versatile lime which can be used for steel in basic oxygen furnaces, sugar refining, magnesia production, chemical industries, metallurgical refining, refractory use, environmental scrubbing, construction, and agricultural and fertilizer application by customizing calcination conditions. Again, the preference for a dry or hydrated lime depends largely on customers and on the volume of intended consumption and the type of storage and handling facilities.

### ➤ Steel Refining

In steel refining NW Tasmanian quicklime can be applied as a flux to remove impurities such as phosphorus, silica, and sulfur. NW Tasmanian dolomitic lime can be substituted for a fraction of the high-calcium lime to extend refractory life. NW Tasmanian dead-burned dolomite, also called refractory lime, can be applied as a component in tar-bonded refractory brick used in basic oxygen furnaces.

According to 1997 statistics Australia produces around 8 million tons of pig iron, around 9 million tons of crude steel, and over 5 thousand tons of semi-manufactured metal. Other than that Australia produces over 190 thousand tons of ferroalloys. A list of the companies is given later in the section.

### ➤ Non-Ferrous Metallurgy

In non-ferrous metallurgy NW Tasmanian lime application can be in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides, and maintain the proper pH in the flotation process. Australia produced around 560 thousand tons of copper ore from more than twenty mining facilities.

NW Tasmanian lime can be used to process alumina via Bayer's process. For treating bauxite the digestion is carried out at moderate temperatures with caustic alkali along with lime. Lime can also be used during wet grinding and caustic recovery stage of the Bayer's process. It can be employed to causticize sodium carbonate solutions to regenerate sodium hydroxide for recyclical use. Recent tests predicted that part or total amounts of this lime can be replaced by dolomite quicklime or lime produced from magnesium rich limestone (with low silica content and other impurities) of NW Tasmanian carbonate rock. The only drawback of using magnesia or dolomite lime is the slower reaction time. However, it will reduce scaling with a better MgO/CaO tail rather than the lime tail in the environmental rehabilitation of the soil. In 1997, Australia mined around 44 million tons of bauxite, and produced over 13 million tons of alumina from six



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refineries. Australia also produced around 1.5 million tons of primary aluminum metal and over 100 thousand tons of secondary metal from its five plants.

NW Tasmanian lime can also be used to extract uranium from gold slimes and to recover nickel by precipitation. Australia mined over 5489 tons of uranium ore in 1997 from its two facilities. Australia mined nickel output in 1997 is around 124 thousand tons and produced around 74 thousand tons of metal from six facilities.

NW Tasmanian lime can be employed in gold and silver recovery operations to control the pH of the sodium cyanide solution used to leach the gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitated tanks. Dump and heap leaching involve crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. NW Tasmanian lime can also be employed to maintain the pH of the cyanide solution at a pH level between 10 and 11 to maximize precious metals recovery and to prevent the creation of hydrogen cyanide gas. The tailings that result from the recovery of precious metals may contain elevated levels of cyanides. Three of the four major treatment processes (Cyanisorb, alkaline chlorination, and sulfur dioxide/air) used to recover these cyanides can use NW Tasmanian lime in the process. Gold output of Australia in 1997 is over 300 tons of primary metal and around 780 kilograms of secondary metal from more than 30 facilities. Silver output of Australia is around 280 tons from its more than 10 facilities.

### ➤ Environmental

In the environmental sector NW Tasmanian lime can be employed in the softening and clarification of municipal potable water to neutralize acid mine and industrial discharges. In sewage treatment lime's traditional role may be to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. It also aided clarification and killing of bacteria. The largest application may be in sewage treatment to stabilize the resulting sewage sludges. Sewage sludge stabilization, also called biosolids stabilization, has as its goal the reduction of odors, pathogens, and putrescibility of the solids. In lime stabilization the basic process involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time. Amount may depend on the local situation in Australia. In a recent letter to potential clients, Dow Chemical Co. in Michigan listed potential advantages of dolomitic quicklime and Mg-hydroxide neutralization over quicklime. There is tremendous cost savings and a better tail of waste. Better, aggressive marketing may find the home for NW Tasmanian dolomitic quicklime in the treatment of mine, industrial, and municipal discharges.

In FGD systems serving utility and industrial plants and incinerators, NW Tasmanian lime can be employed to react with sulfur oxides in the flue gas and can be used to stabilize the resulting sludge before disposal. This market in Australia is dependent on electricity demand. Lower demand for electricity means lower demand for coal by utility companies and thus lower demand for FGD lime for scrubbing.

### ➤ Pulp and Paper Industries

NW Tasmanian lime can be used by the pulp and paper industry in the basic Kraft pulping process where wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. NW Tasmanian lime can be used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a

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recovery furnace where dissolved organics are burned to recover waste heat and where sodium sulfide and sodium carbonate are recovered. The recovered sodium sulfide and sodium carbonate are diluted with water and then can be treated with NW Tasmania slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse. The paper industry used lime as a coagulant aid in the clarification of plant process water. These industries have their own suppliers and it is very difficult to penetrate this market.

**➤ Chemical Industrial**

NW Tasmanian lime can be used in other chemical industrial applications. The lime can be used in the manufacture of alkalis. NW Tasmanian quicklime can be used in large quantities to recover ammonia in the manufacture of soda ash and sodium bicarbonate by the solvay process where some 635 kg of quicklime are required per short ton of soda ash. Calcium carbide, formerly the main source of acetylene, can be manufactured through the fusion of NW Tasmanian quicklime and coke at very high temperatures. Chlorine and hydrated lime can be reacted together to produce sources of dry bleach in the form of high-test calcium hypochlorite and chloride of lime. Other chemicals can be made from NW Tasmanian lime are magnesia, calcium phosphates, chrome chemicals, pesticides, and paint pigments. NW Tasmanian lime can also be used in the manufacture of ethylene and propylene glycol, calcium based organic salts, refining citric acid and glucose, and dyes. However, this is a small market with extensive marketing requirements and may not be economically feasible at this stage of the process.

**➤ Sugar Refining**

NW Tasmanian quicklime can be employed in sugar refining however, sugar refineries have their own calcining facilities and captive suppliers. In sugar refining milk of lime was used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself was then removed by reaction with carbon dioxide to precipitate calcium carbonate. The carbon dioxide was obtained as a by-product of lime production.

**➤ Construction**

In construction NW Tasmanian lime can be used for soil stabilization to upgrade clay soils into satisfactory base and subbase materials. Common applications include the construction of roads, airfields, building foundations, earthen dams, and parking areas. Sales for soil stabilization increased over the years in Australia. NW Tasmanian quicklime can be used in autoclaved aerated concrete to produce building materials that could be cut, drilled, and nailed like wood but with the advantages of a concrete product. NW Tasmanian hydrated lime can be used with fly ash to make a base material, in asphalt mixes to act as an anti-stripping agent, and in plaster, stucco, and mortar to improve durability.

**➤ Refractory and Others**

NW Tasmanian dead burnt or hard burnt dolomite or refractory lime can be used both in brick and shape manufacture and for monolithic refractories. To achieve refractory grade, dolomite must be burned at elevated temperatures to drive off contained CO<sub>2</sub>. The material is sintered, hard burned or dead burned at elevated temperatures (1300 - 1800 C) to produce a much denser, more inert product (dead or hard burned dolomite, refractory lime or doloma). The actual sintering temperature varies depending on the purity and properties of the material. The chemical composition and bulk specific gravity of the burnt product are most important properties. The most important market for the dead burned material is open-hearth furnaces,

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basic oxygen furnaces, ladle linings, argon oxygen decarburization vessels, cement kilns, and some cases electric arc furnaces.

The NW Tasmanian dolomitic quicklime can be used as a flux in the manufacture of glass; quicklime can be used to make calcium silicate building products such as sand-lime brick; and hydrated lime can be used to produce silica refractory brick. The demand for this industry is difficult to predict and is dependent on county economy.

**➤ Agriculture**

NW Tasmanian lime or dolime will find good applications in agricultural use. It will neutralize soil acidity through base exchange with the calcium and magnesium cations displacing the hydrogen ions in the soil. This process results in a 15 to 40% increase in crop yield. The optimum grain size is less than 1.25 - 0.18 microns as a free flowing powder. Again, this market is dependent on government agricultural policies and farmers willingness to apply it to his fields.

**7.2.3 Chemical from NW Tasmanian Carbonate**

The NW Tasmanian carbonate material can be processed further to obtain chemicals for various other chemical and metallurgical applications. This is mainly applied to dolomite or magnesian limestone. The main chemicals from ores are Mg metal, MgO, Mg-hydroxide, Mg-carbonate and other magnesia compounds. However, this market is very small, has a captive supplier, and is very difficult to penetrate.

**7.3 New Areas of Application for Calcined Carbonate Ore (Lime)**

In steel refining NW Tasmanian modified carbonate ore can be applied as a flux in place of limestone or lime to remove impurities such as phosphorus, silica, and sulfur. Over the years industrial practice has showed that pure dolomitic quicklime substituted for the portion of the high calcium flux resulted in greater refractory life. In the UK they add 55.9 kg of lime and 22.4 kg of burnt dolomite per tonne of steel produced in oxygen steel plants. Magnesian-limestone lime may be an excellent source to use as a flux because it contains the necessary average composition of calcium and magnesium in one rock/ore.

Other areas where magnesium rich limestone lime or dolomitic lime can be employed is in neutralization of industrial waste. In a recent letter to potential clients Dow Chemical Co. in Michigan listed potential advantages of dolomitic quicklime and Mg-hydroxide neutralization over quicklime. Even though it is a slow neutralization process, it saves large amounts of money in waste neutralization and generates a good trail of by-product. For example, caustic soda price in the US is around \$380 per ton in 1998 and lime/dolime is around \$55 per ton.

Dolomitic lime or magnesium rich lime can also replace lime in non-ferrous industries. The advantage here is the economy and large savings. The drawbacks are slower reaction and hydration time (approximately three order of magnitudes slower). An example is the pure, low silica dolime or magnesia rich lime can replace quicklime in Bayer's process to produce alumina. Testing is going on in Q.A.L. Australia in this direction. If this is employed there is tremendous savings with less impurities in the system. It will also reduce scaling and create a better MgO/CaO tail rather than lime tail in the environmental rehabilitation of the soil.

Dolomitic limestone or lime can be employed in place of limestone in coal dust blend and glass applications. The rest of them are covered in the application section.



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**7.4 Advantages for MHA for Marketing NW Tasmanian Carbonates**

- Carbonate is marbleized and crypto-crystalline in nature.
- Material is very pure with very little fines or dust.
- There is a possible availability of a low cost calcining facility nearby. A mineral processing facility is located at Port Latta and has 5 vertical calciners with 2 million tonnes processing capabilities per annum.
- The facilities are near seaboard with good infrastructure and they are located chiefly in sparsely populated, undulating and cleared forest, and in farming country without environmental problems.
- Australian Bulk Minerals, owners of the Port Latta facility, are likely to facilitate the construction of a loading pad alongside the facility to stack and load carbonates.
- There is a possibility of establishing stockpile of carbonates on the wharf at the iron ore operation at Port Hedland in the Pilbarra or at the bauxite wharfs at Kernerton, W.A., Weipa and Gove, in N.T. There is also a possibility to stockpile them at these port terminals by shipping them economically in vessels that normally return in water ballasts after delivering alumina and iron ore from the east coast of Australia.

**7.5 Iron and Steel Companies in Australia and Southeast Asia**

These are possible companies where MHA can market their carbonate ore as a flux.

➤ **Australia**

New South Wales:	Mayfield	Broken Hill Pty. Co. Ltd (BHP Refractory Pty. Ltd.)
	Newcastle	Broken Hill Pty. Co. Ltd (Newcastle Works.)
	Port Kembla	Broken Hill Pty. Co. Ltd (Springhill Works)
	Sydney	Broken Hill Pty. Co. Ltd
		Nippon Steel Australia Pty. Ltd
	Wollongong	Broken Hill Pty. Co. Ltd (Port Kembla Steel Works)
Queensland:	Acacia Ridge	Broken Hill Pty. Co. Ltd (Brisbane Market Mill.)
	Rooty Hill	Broken Hill Pty. Co. Ltd (Sydney Steel Mill.)
South Australia:	Whyalla	Broken Hill Pty. Co. Ltd (BHP Whyalla Operation)
Victoria:	Geelong	Broken Hill Pty. Co. Ltd (Geelong Rod Mill.)
	Hastings	Broken Hill Pty. Co. Ltd (Western Port Works)
	Melbourne	Broken Hill Pty. Co. Ltd (BHP Refractory Pty. Ltd.)



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### ► Japan

Amagasaki	Nisshin Steel Co (Amagasaki Wks)
Chiba	Kawasaki Steel Corp (Chiba Wks)
Handa	Kawasaki Steel Corp (Chita Wks)
Hikari City	Nippon Steel Corp (Hikari Wks)
Himeji City	Nippon Steel Corp (Hirohata Wks)
Ichikawa City	Nissin Steel Co (Ichikawa Wks)
Kakogawa	Kobe Steel Ltd (Kakogawa Wks)
Kamaishi City	Nippon Steel Corp (Kamaishi Wks)
Kimitsu City	Nippon Steel Corp (Kimitsu Wks)
Kitakyushu City	Nippon Steel Corp (Yawata Wks)
Kobe	Kawasaki Steel Corp (Hanshin Wks) Kobe Steel Ltd. (Kobe Wks)
Kurashiki	Kawasaki Steel Corp (mizushima Wks)
Kure City	Nisshin Steel Co (Kure Wks)
Muroran City	Nippon Steel Corp (Muroran Wks)
Oita City	Nippon Steel Corp (Oita Wks)
Osaka	Nisshin Steel Co (Osaka Wks)
Sakai City	Nippon Steel Corp ( Sakai Wks) Nisshin Steel Co (Sakai Wks)
Shin Nanyo City	Nisshin Steel Co ( Shunan Wks)
Takasago	Kobe Steel Ltd Takasago Wks
Tokai City	Nippon Steel Corp (Nagoya Wks)
Tokyo	Kawasaki Steel Corp Nippon Steel Corp (Tokyo Wks)



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Nisshin Steel Co

NKK Corp

➤ **Korea**

Pohang City Pohang Iron and Steel Co (POSCO)

➤ **New Zealand**

South Auckland BHP New Zealand Steel Ltd

➤ **Taiwan**

Kaohsiung China Steel Corp

**8. APPENDIX**

**8.1 The Mineral Industry of Australia**

Australia is estimated to be the third largest producer of minerals and metals excluding coal and petroleum in the world, and its minerals industry is a leading catalyst in promoting the growth of the economy. The country's gross domestic product (GDP) in fiscal year 1996-97 (July-June) was A\$491.3 billion (about \$359 billion). The minerals industry represented \$23.3 billion or 6.5% of the Australian economy (Minerals Council of Australia, 1998, Current economic impacts in Australia, accessed July 7, 1998, on the World Wide Web at URL <http://www.minmet.uq.au/ugrad/courses/5e103/aspin/notes18.html>). The real GDP growth rate for 1997 was 2.9 (U.S. Energy Information Agency, May 1998, Australia, accessed May 21, 1998, on the World Wide Web at URL <http://www.eia.doe.gov/emeu/cabs/australi.html>).

In 1997, Australia was the world's leading producer of alumina, bauxite, chrysoprase, diamond, ilmenite, monazite, opal, rutile, sapphire, and zircon, second largest producer of lead and zinc, third largest producer of gold and iron ore, fourth largest producer of cobalt and uranium, and the fifth largest producer of aluminum, coal, copper, nickel, and silver. It was the premier exporter of alumina, coal, ilmenite, iron ore, refined lead, monazite, rutile, and zircon. The country's mineral wealth is so extraordinary that it is virtually self-sufficient in most mineral commodities. The only significant mineral resource in which Australia is not self-sufficient is petroleum (Digital Reflections, 1998, Mining and exploration—Australia and New Guinea, accessed April 17, 1998, on the World Wide Web at URL <http://www.reflections.com.au/MiningandExploration/>). Australia, nevertheless, produced more than 80% of its crude oil requirements domestically in 1997 (U.S. Energy Information Agency, May 1998, Australia, accessed May 21, 1998, on the World Wide Web at URL <http://www.eia.doe.gov/emeu/cabs/australi.html>). Australia also is endowed with abundant resources of other mineral fuels including coal, natural gas, liquefied petroleum gas and uranium, and continues to be one of the few market economy countries that is a net exporter of mineral fuels.



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### 8.1.1 Government Policies and Programs

At year end 1996, the Government announced that the foreign investment policy in relation to Australian uranium projects would be the same as that for any other mineral meaning that although prior approval still is required, no special restrictions will apply unless the project appears to be contrary to national interest. Uranium export controls would continue to implement safeguards (UIC Newsletter, 1997b).

Attempts by the Government to reform native title legislation were stalemated at year end. The Government's declared aim was to end the confusion resulting from the Wik ruling that was made by the High Court in the final days of 1996. Prior to the Wik ruling, the right of aboriginal people to claim land was restricted to vacant land owned by the Government, about 36% of Australia, and then only if they had maintained a continuing association with the land being claimed. The Wik ruling threw the issue into confusion because it allowed the possibility of native title extending to land held under lease, thus increasing the proportion of land open to possible native title claim to about 78% of the country (Mining Journal, 1997c).

### 8.1.2 Environmental Issues

In October the Government set its goal to contain greenhouse gas emissions at an 18% increase from 1990 levels by 2120 (instead of the projected 28% increase without restraint). Included with the \$130 million that will be spent to achieve this goal was a requirement that electricity retailers source an additional 2% of electricity from renewable sources by 2010 (UIC Newsletter, 1997a).

### 8.1.3 Production

Of the total \$23.3 billion mineral and energy production in 1997, metallic minerals contributed an estimated 40%; petroleum (crude oil, natural gas, and natural gas liquids), 30%; coal, 25%; and industrial minerals (clays, construction materials, dimension stone, peat, and salt), 5%.

Australia remained the world's leading producer of alumina, bauxite, chrysoprase, diamond, ilmenite, monazite, opal, rutile, sapphire, and zircon. The country also continued to rank among the world's top producers of aluminum, antimony, coal, cobalt, copper, gold, iron ore, lead, manganese, nickel, salt, silver, tin, uranium, and zinc.

### 8.1.4 Trade

Australia continued to rely heavily on the export of the majority of its mineral production to bolster economic growth. Mineral exports were concentrated in just four commodity groups in descending order - coal, gold, alumina-aluminum-bauxite, and iron ore (U.S. Embassy, Canberra, Australia, 1998b). The mineral industry remained Australia's largest export earner accounting for more than 60% of commodity export earnings (Minerals Council of Australia, 1998, Current economic impacts in Australia, accessed July 7, 1998, on the World Wide Web at URL <http://www.minmet.uq.au/ugrad/courses/5e103/aspin/notes18.html>). An estimated 80% of Australia's mineral production was exported. Australia remained the premier exporter of alumina, coal, ilmenite, iron ore, refined lead, monazite, rutile, and zircon. By using its plentiful resources of energy minerals (coal, liquefied natural gas, and uranium), Australia also continued to be a net exporter of mineral fuels.



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### 8.1.5 Structure of the Mineral Industry

The Australian mineral industry covers nearly the whole spectrum of minerals, major industrial minerals (ilmenite, rutile, and zircon), base metals (copper, lead, and zinc), ferrous metals (iron ore, manganese, and nickel), non-ferrous metals (aluminum and tin), precious metals (gold and silver), fuel minerals (coal and uranium), and gemstones (diamond, opal, and sapphire). Australia is one of the world's principal producers and suppliers of ores, concentrates, and refined metals. Australia is estimated to rank third in the world in the value of its non-fuel mineral production. The value of its mineral production including the fuels is estimated to rank eighth in the world.

The Australian mining industry is based on a system of free enterprise in which private companies are involved in exploration, mine development, production, mineral processing, and marketing. A number of foreign companies in Australian mineral ventures are affiliates or subsidiaries of US companies. Foreign companies control a majority of the mining, smelting, and refining sectors and a significant portion of the petroleum and natural gas sectors.

Many of Australia's mineral industries are fully integrated producing ores, concentrates, and other intermediate products (for example, alumina), and refined metal or other end products (for example, cut-and-polished gem diamond) within the country. In 1997 there were six alumina refineries and six smelters, three principal copper smelters and three principal refineries, one principal gold refinery, four principal lead-zinc smelters and/or refineries, one manganese ferroalloy plant, one nickel smelter and two nickel refineries, three principal crude steel plants, one primary tin smelter, the end of its economic life. Construction to expand Huntly's one tin refinery and two secondary tin refineries, two silver refineries, and eight principal petroleum refineries.

Ownership of mineral rights in Australia is divided between State ownership in State onshore areas and Commonwealth (Federal) ownership in Territories and in offshore areas beyond Australia's territorial limit. The Commonwealth's responsibility for minerals in the Northern Territory, except for uranium has, however, been transferred to the Government of the Northern Territory thus, the individual States and Territories administer the mineral industries within their own borders including registering land titles, issuing exploration and development permits, overseeing mining operations including administration of inspections, assuring compliance with health, safety, and environmental regulations, and levying royalties and taxes.

The Federal Government may restrict mineral exports for the good of the country and therefore has de facto control over most mineral production.

## 8.2 Australian Commodity Review Related to Carbonate Ore Application

### 8.2.1 Metals

**Bauxite, Alumina, and Aluminum:** For the 27th successive year Australia was the unchallenged world leader in bauxite production. Production was from the open-cut operations at Weipa on the western flank of Cape York Peninsula in the far north of Queensland, the Gove operation across the Gulf of Carpentaria in northeastern Arnhem Land, Northern Territory; and the mines south of Perth in the Darling Ranges, Western Australia. Substantial bauxite deposits also border Admiralty Gulf at Cape Bougainville and in the nearby Mitchell Plateau area of the Kimberley region of Northern Western Australia, but their remoteness from energy supplies and infrastructure has prevented their development. Australia was also dominant in alumina production in 1997 with output coming from six refineries, four in Western Australia and one each in the Northern Territory and Queensland. Ranking fifth in the world in 1997, Australia

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also was a significant producer of aluminum. Aluminum was produced at six smelters, two each operating in New South Wales and Victoria, and one each operating in Queensland and Tasmania.

In February Alcan South Pacific Pty. Ltd., a subsidiary of Canada's Alcan Aluminium Ltd. (Alcan), announced plans to develop a 2.5 million metric ton per year (Mt/yr) mine at its Ely bauxite deposit following a feasibility study that confirmed viability. First production was initially expected in 1999 with 1 million metric tons (Mt) of bauxite going to Alcan's Anghinish alumina refinery in Ireland (Mine Development Business Leads, 1997). Early in 1998, however, Alcan reached an agreement to take bauxite from Comalco Ltd. (Mining Journal, 1998a). The Ely deposit is adjacent to Comalco's Weipa Mine.

Alcoa of Australia Ltd.'s (Alcoa) Huntly Mine in Western Australia was scheduled to become the biggest bauxite mine in the world by the end of 1998, and to produce more bauxite each year (18 Mt) than any nation other than Australia itself and Guinea. Alcoa will compensate for the loss of 6.8 Mt/yr of bauxite production from the scheduled closing of the Jarrahdale Mine by expanding output from its nearby 11.9 Mt/yr Huntly Mine. Jarrahdale, in operation since 1963, was scheduled to close at the end of 1998 after reaching the end of its economic life. Construction to expand Huntly's operations began in August to enable commissioning of the required new facilities by year end 1998 (Alcoa of Australia Ltd., 1997, p. 10). Eventually Alcoa expects Huntly to supply all the bauxite requirements for its 1.9 Mt/yr Kwinana and 3.1 Mt/yr Pinjarra alumina refineries. The plans will not affect Alcoa's third bauxite mine at Willowdale (Mining Journal, 1997j).

In September Worsley Alumina Pty. Ltd., operator of the Worsley Joint Venture, announced a \$600 million expansion at the Worsley alumina refinery and associated Mount Saddleback bauxite mine near Boddington, about 100 kilometers (km) south of Perth, Western Australia. Construction of a third reduction potline will increase alumina production from about 2.5 to 3.5 Mt/yr, making it the largest capacity refinery in Australia. Reynolds Australia Alumina Ltd. was the majority owner (56%) in the joint venture, the only bauxite to alumina project venture with Japanese shareholders (Metal Bulletin, 1997b).

In November Alcoa began construction on the \$193 million expansion of its Wagerup Refinery. The expansion will increase operating capacity from 1.75 Mt/yr of alumina to 2.19 Mt/yr and is the first stage of a planned 3.3 Mt/yr expansion. Alumina output from the facility was scheduled to begin in mid-1999 (Alcoa of Australia Ltd., 1997, p. 3).

At year end Comalco was evaluating the siting of a \$975 million greenfield alumina refinery that would use bauxite from its Weipa deposits. Two sites were under consideration, Bintulu in Sarawak, Malaysia, and Gladstone, Queensland (Comalco Ltd., 1997, p. 14). The proposed refinery would have a capacity of 1.4 to 1.6 Mt/yr (Resource Information Unit, 1998, p. 65).

In mid-year Comalco's majority owned Boyne Island Smelters Ltd. completed the \$750 million expansion of its Boyne Island aluminum smelter south of Gladstone. Capacity at the smelter was increased from 260,000 to 490,000 metric tons per year (t/yr) of aluminum through the addition of a third potline consisting of 264 cells. The expansion was commissioned in October, six months ahead of its original schedule and within budget (Comalco Ltd., 1997, p. 15).

In September the State of Victoria announced that it planned to privatize its aluminum holding company, ALUVIC, in the first half of 1998. ALUVIC holds a 25% interest in the Portland aluminum smelter in Portland, Victoria, plus an indirect interest through its 16% share in Eastern Aluminium Ltd., which holds a 10% stake in the smelter (Mining Journal, 1997f).



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### ► Copper

Mine production of copper in Australia was either as the primary product or a co-product mainly from mines that produce other metals. The most notable copper producing operations in Australia are at Mount Isa, Queensland (Hilton copper-lead-zinc mine), and Roxby Downs Station, South Australia (Olympic Dam copper-gold-uranium mine). In 1997 Australia copper production ranked fifth highest in the world with only Chile, the United States, Canada, and Indonesia producing more.

In June Aberfoyle Ltd. announced a \$125 million expansion of its Gunpowder-Mammoth open cut mine 125 km north of Mount Isa, following completion of a 12-month feasibility study. The expansion, to be completed during September quarter 1998, will increase output to the equivalent of about 44,000 t/yr of copper cathode for 6 years, then decrease to the equivalent of 35,000 t/yr copper cathode during the subsequent 4 years (Mining Journal 1997a).

Following a successful pilot scale bacterial oxidation plant at its Mount Lyell copper mine in Tasmania, Copper Mines of Tasmania Pty. Ltd., a wholly owned subsidiary of Mount Lyell Mining Co. Ltd. (formerly Gold Mines of Australia Ltd.), started the second phase of its feasibility study into the use of bacterial oxidation to extract copper from copper concentrate. The second phase was to determine the commercial viability of the process (Mining Journal, 1997g).

In October demolition and redevelopment work began on the 80,000 t/yr Port Kembla copper smelter near Wollongong, New South Wales that was placed on care and maintenance in 1995 by the former owner CRA Ltd. (now Rio Tinto Ltd.), rather than invest \$150 million in substantial environmental and technical improvements. The new owners, a consortium of Japanese firms led by Furukawa Co. Ltd., planned to spend about the same amount to install an MIM Holdings Ltd.-designed tank house along with converting equipment and to carry out an environmental upgrade of an accompanying sulfuric acid plant. One-half of the smelter's 400,000-t/yr copper concentrate feed was expected to come from domestic mines (Mining Journal, 1997k). Reconstruction of the smelter was made possible when legislation passed in mid-year by the New South Wales Government eased the burden of environmental compliances (Mining Journal, 1997e).

The Ernest Henry open-cast copper-gold mine was commissioned in October after construction was completed 2 months ahead of schedule and more than \$26 million under budget. Ernest Henry, 30 km northeast of Cloncurry, Queensland, was designed to produce 95,000 t/yr of copper at full capacity during the fourth production year. All the concentrates will be processed at MIM's Mount Isa Smelter and the Townsville Refinery (van Os, 1997). An injunction to restrain Ernest Henry Mining Pty. Ltd., the mine's operator-manager, from mining was sought by the Mitakoodi-Juhnjar aboriginal people in their challenge of the validity of the mining leases granted by the Queensland Government in 1974 and renewed in 1995. The basis of their claim was that the Queensland Government had not followed the correct process established under the Native Title Act. The matter was still pending at year end (Resource Information Unit, 1998, p. 101).

In December environmental clearance was granted for the \$1.1 billion extension to WMC's huge Olympic Dam polymetallic operation at Roxby Downs Station. The clearance applied to any production increase up to 200,000 t/yr of copper plus associated products. WMC began the expansion in the latter part of 1996 to boost copper output from 85,000 to 200,000 t/yr, originally to be completed by 2001 but later rescheduled forward to mid-1999. WMC also applied for environmental approval for eventual production of 350,000 t/yr of copper (Mining Journal,



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1997i). Olympic Dam was the sixth largest copper ore body in the world (Minerals Gazette, 1996a).

### ► Gold

Gold is mined in all six States and the Northern Territory. Australia remained the world's third largest gold producer after South Africa and the United States. Western Australia remained the premier gold mining State in Australia producing more than 75% of the country's output (Australian Bureau of Agricultural and Resource Economics, 1998, p. 15). Gold is the second largest export earner after coal (Mining Journal, 1997o). The Kalgoorlie Super Pit in Western Australia was the largest single producer with production capacity of more than 21,000 kilograms per year (kg/yr) of gold (Metal Bulletin, 1998c). Total gold production in 1997 was a record high 311 t, nearly an 8% increase from that of 1996 (Mining Journal, 1998b).

Development of Acacia Resources Ltd.'s \$35 million Sunrise Dam surface mine and plant was completed ahead of schedule and under budget, and the mine began commercial production in April after a successful commissioning phase. Since then the plant has operated at 120% of design capacity resulting in higher-than-forecast gold recovery. The waste-to-ore ratio in the pit was less than one-half that projected resulting in a significant increase in the amount of ore fed to the plant. As a result, production by year end was more than double the 4,500 kilograms (kg) originally forecast (Resource Information Unit, 1998, p. 291).

In June the Reserve Bank of Australia, an agency of the Federal Government, announced that it had secretly sold 167 t of gold, two-thirds of its total holdings, during the previous 6 months, setting off a drop in the gold index of more than 10% and a decrease in the value of Australian gold shares by almost \$2 billion. Although the price of gold continued to drop to a 12-year low later in the year, it was uncertain whether the Reserve Bank's gold sale was ultimately responsible for the decrease in prices (van Os, 1998).

The Western Australia Government introduced a gold royalty effective July 1. The 1.25% initial royalty assessed on production of more than 2,500 ounces (Mining Journal, 1997q), equivalent to approximately 77.76 kg, will increase to 2.5% in July 2000 if the average spot price for gold increases above A\$450 per ounce, equivalent to approximately \$331 per ounce, by 2005, no matter what the price of gold may be, the present royalty arrangements will be extinguished and a flat rate of 2.5% will be imposed (Mining Journal, 1997p).

The Ernest Henry copper-gold project was officially opened in October ahead of schedule and under budget. The mine near Cloncurry was to produce 120,000 ounces per year of gold when mining reaches full optimization of 1.5 Mt/yr of ore during the fourth year of production (Mining Journal, 1997n).

In November Pegasus Gold Australia Pty. Ltd. placed its Mount Todd Mine in the Northern Territory on care and maintenance owing primarily to low metal prices and high operating costs. Originally begun as a heap-leaching operation, the mine was progressively transformed after the addition of a crushing and milling plant in 1996. A second expansion program to increase nominal throughput capacity to 8 Mt/yr included flotation, regrinding, leaching, and a four-stage crushing circuit. A new 35-megawatt gas turbine power plant also was included in the expansion, and first gold from the new complex was poured in January 1997 (Resource Information Unit, 1998, p. 147).



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### ► Iron Ore and Steel

Australia was the world's largest exporter of iron ore for the fourth (revised) successive year with shipments totaling 152 Mt valued at about \$2.6 billion. The country supplied 15% of the world's iron ore market, representing 36% of global seaborne trade, and 77% of its shipments were destined for integrated steelmakers in Asia (Mining Journal, 1998d). As a world producer Australia ranked third behind China and Brazil. Iron ore production continued to be concentrated in the Hamersley Range of the Pilbara region, Western Australia, which accounted for more than 97% of the country's production. Iron ore also was produced by BHP Steel Pty. Ltd. at its Iron Baron, Iron Duke, and Iron Knob Mines in the Middleback Range near Whyalla, South Australia. BHP Iron Ore Pty. Ltd. was Australia's largest producer of iron ore with major mines at Goldsworthy, Jimblebar, Mount Newman, and Yandi, all in the Pilbara region. Iron ore from BHP Iron Ore's mines is railed to Nelson Point and Finucane Island, on opposite sides of the harbor at Port Hedland. BHP Iron Ore is the second largest iron ore producer in the world after Brazil's Cia. Vale do Rio Doce (Metal Bulletin Monthly, 1998).

Hamersley Iron Pty. Ltd., a part of the international mining giant Rio Tinto, operates the mines Brockman No. 2 Detrital, Channar (60% Hamersley), Marandoo, Mount Tom Price, and Paraburdoo in the Hamersley region of the Pilbara. The company, Australia's second largest iron ore producer, owned and operated railway links from Paraburdoo through Tom Price to the port of Dampier, Western Australia, 386 km away where Hamersley shipped to steel mills in China, Japan, the Republic of Korea, Taiwan, and Europe. Spur lines connect the Brockman No. 2 (44 km) and the Marandoo (59 km) Mines; the Channar Mine is linked to Paraburdoo by overland conveyor. Hamersley shipped a record 60 Mt of iron ore in 1997, 80% going to Asia (Metal Bulletin, 1998a). In September Hamersley committed to the development of its \$510 million Yandicoogina operation. Capacity at the mine was expected to increase to 15 Mt/yr from initial production of 5 Mt/yr in 1999 (Resource Information Unit, 1998, p. 315).

Robe River Iron Associates, with a capacity of 27 Mt/yr, was Australia's third largest iron ore producer and the fourth largest in the world. The principal iron ore deposits are located in mesas stretching about 100 km along the Robe River valley near the company town of Pannawonica in Western Australia. Robe River's processing and port facilities are at Cape Lambert, Western Australia, about 200 km to the northeast. The Mesa J iron ore deposit was the company's production base providing sinter fines for export (Bachman, 1997, p. 30).

Koolyanobbing Iron Pty. Ltd., a 60-40 joint venture of Portman Mining Ltd. and China's Anshan Iron and Steel Corp., operated the Koolyanobbing iron ore mine, 50 km north of Southern Cross, Western Australia. The mine produced lump and fines ore in about equal quantities. All fines were shipped from Koolyanobbing Iron's port at Esperance to Anshan Iron under a 20-year sales contract approved in 1994. The lump ore was shipped to Anshan Iron and other Chinese steelmakers as well as to Japanese integrated steelmakers. Koolyanobbing Iron also operated the iron ore beneficiation plant on Cockatoo Island off the northern coast of Western Australia, 140 km north of Derby (Bachman, 1997, p. 32).

The contribution of BHP Steel, the only integrated steel producer in Australia to total world steel output is small, ranking 20th in the world and producing about 1% of world production (Metal Bulletin, 1998b). BHP Steel's steelworks are at Newcastle, Port Kembla, and Whyalla. BHP Steel announced the closing of the Newcastle plant but is conducting a \$90 million feasibility study for constructing a new facility (Stewart, 1998, p. 13).

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Near year end the Government awarded a \$4.7 million research and development grant to the South Australian Steel and Energy (SASE) Project. The grant will enable construction of a demonstration plant at Whyalla that will use Ausmelt Ltd.'s patented Ausiron furnace technology to produce pig iron. Although this technology has been used on a commercial scale the demonstration plant will allow more measurement of operating parameters, thus paving the way for the \$700 million SASE Project to produce 2.5 Mt/yr of low cost pig iron for export to Southeast Asia (Mining Journal, 1997d).

Brisbane-based Goldamere Pty. Ltd., trading as Australian Bulk Minerals (ABM), reopened the Savage River iron ore mine and pellet plant in Tasmania in November (Resource Information Unit, p. 316). ABM acquired the mine in March 1997 after it was closed by the former owner-operator Pickands Mather and Co. International of the United States, after almost 30 years of production. ABM was planning to produce 500,000 t/yr of pig iron by using new technology and constructing a mini steelworks.

### 8.2.2 Silver

Australia was a major silver producer in 1997, ranking fifth largest in the world after Mexico, Peru, the United States, and Canada. Most of the country's production, however, continued to be a by-product of copper-gold, gold, or lead-zinc mining.

Production of by-product silver from the Olympic Dam Mine will increase from about 12,500 to about 30,000 kg/yr as a result of a progressive expansion program scheduled to be completed in mid-1999, 18 months earlier than originally planned (Resource Information Unit, 1998, p. 108).

The first lead and zinc concentrates containing 3,000 grams per ton (g/t) and 300 g/t silver, respectively, were produced in October at the Cannington lead-zinc-silver mine 200 km southeast of Cloncurry (Resource Information Unit, 1998, p. 326). The lead 1998 silver and zinc-silver concentrates were to be railed to Townsville for further shipment to Pasminco's and other smelters to yield a maximum of 750 t/yr silver (Mining Journal, 1997b). At the full production rate of 1.5 Mt/yr of ore, expected to be achieved by mid-1998, the Cannington Mine will account for about 6% of the world's mine output of silver (Mining Journal, 1997n).

### 8.2.3 Industrial Minerals

#### ➤ Cement

Five industrial conglomerates accounted for most of the country's cement capacity and they held large share percentages of a multitude of plants around the country - Adelaide Brighton Cement Ltd. held the most, about 2.1 Mt/yr of capacity, or a 29% share; Blue Circle Southern Cement Ltd. approximately 2 Mt/yr, or 28%; Australian Cement Holdings Ltd., about 1.4 Mt/yr, or 20%; Queensland Cement Ltd., about 1.3 Mt/yr, or 18%; and Cockburn Cement Ltd., 0.3 Mt, or about 4%.

#### ➤ Magnesia

Cryptocrystalline magnesite has been mined since 1992 by Queensland Metals Corp. (QMC) at the Kunwarara Mine, 70 km northwest of Rockhampton in Queensland, through the Queensland Magnesia (QMAG) project for the production of deadburned and electrofused magnesia used as feedstock for refractory materials. QMAG is also a research organization focusing on refractory applications and the research and development of calcined building materials.



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The Magnesium Metal Project, a 50-50 joint venture of QMC and Commercial Minerals Ltd., a wholly owned Normandy Mining Ltd. subsidiary, was formed early in the year to develop process technology for producing magnesium metal and alloys from magnesite ore. In February construction began on a 1,000-t/yr pilot plant at Gladstone, 160 km from the Kunwarara Mine. A full-scale feasibility study of a commercial-scale operation was to follow. The cost of this first phase of the project, expected to take 2½ years to complete, was estimated to be \$56 million. This work was expected to result in a decision as to whether or not to construct a plant to produce 90,000 t/yr at an estimated cost of \$539 million (Mining Journal, 1997m).

### 8.2.4 Mineral Fuels

#### ► Coal

In 1997, the coal industry was Australia's largest foreign-exchange earner (U.S. Embassy, Canberra, Australia, 1997c), accounting for an estimated 25% of export revenues from the minerals sector and about 15% of the country's export earnings (Mining Journal, 1998c). Australia was the sixth largest coal producer (all grades) in the world (Coal Age, 1997b). New South Wales and Queensland accounted for more than 98% of the country's black coal production and virtually all its exports. The principal areas of coal production were the Bowen Basin, Queensland; Hunter Valley, Western Coalfield, and South Coast Coalfield, New South Wales; Leigh Creek, South Australia; Fingal, Tasmania; Latrobe Valley Coalfield (all brown coal), Victoria; and near Bunbury, Western Australia. The Northern Territory had no coal production.

In 1997, Australia retained its position, held since 1984, as the world's largest exporter of coal (Edwards, 1997). Coal exports were shipped from nine terminals at seven ports along the country's eastern coast. Australia controlled an estimated 35% to 40% of the world's seaborne coal trade by exporting more than 70% of its salable coal production of more than 215 Mt in 1997. The major market for Australia's coal exports was Japan and other Asian countries. Significant amounts of coal also were exported to Europe, the Indian subcontinent, the Middle East, and South America (Australian Bureau of Agricultural and Resource Economics, 1998, p. 11-12).

BHP Coal Pty. Ltd.'s Mount Owen Mine in New South Wales officially opened in March. BHP Coal, which acquired the mine when it purchased the assets of Hunter Valley Coal Corp. in 1995, upgraded it from 1 to 3.55 Mt/yr to meet the demand from the growing Asian thermal coal markets. Thiess Contractors Pty. Ltd., which constructed a 7-km rail spur and a washing plant, also operated the mine, and Mount Owen became the first coal mine in Australia to operate under a partnering agreement (Resource, Information Unit, 1998, p. 75).

In June the joint-venture partners of the Central Queensland Coal Associates announced plans to spend \$375 million on expansion of the Peak Downs and the Saraji open-cut coking coal mines and Hay Point port facilities. The expansion will increase output at Peak Downs by 3 Mt/yr to 10 Mt/yr by the last semester of 2001 through the addition of a new large dragline and added stripping, hauling, and processing capacity. Capacity at the Saraji Mine will increase from 5 to 7 Mt/yr. The ongoing expansion of Hay Point will increase shipping capacity from 24 to 28 Mt/yr (Mining Journal, 1997l).

Majority owner Portman (95%) approved plans in October that will nearly double production from 2 to 4 Mt/yr of salable coal at its Burton Mine. The mine began commercial production in January. Construction was scheduled to start in early 1998 with expansion to be completed near year end (Coal Age, 1997c).



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The Gordonstone Mine, Australia's highest-capacity longwall mine with output exceeding 4.6 Mt in 1996, was placed on care and maintenance in October. The majority owners, two subsidiaries of the fourth largest U.S. coal producer, Atlantic Richfield Co.(ARCO), closed the mine following higher production costs, lower output, and poorer profit margins (Resource Information Unit, 1998,p. 83). ARCO was considering the disposal of all its Australian and U.S. coal mining operations and withdrawing from the worldwide coal business (Coal Age, 1997a).

In December majority-owner MIM announced it would develop a new underground longwall section at its Oaky Creek Mine in Bowen Basin. The expansion will nearly double mine output to 6 Mt/yr of coking coal. Improved dragline efficiencies at the open-cut operations were expected to maintain their 1.8-Mt/yr capacity (Mining Journal, 1997h).

### ► Uranium

The existence of uranium in Australia has been known since the 1890's. In the 1930's, ores were mined at Radium Hill and Mount Painter in South Australia to recover minute amounts of radium for medical purposes. As a result a few hundred kilograms of uranium were also produced and used as a bright yellow pigment in glass and ceramics. Uranium ores as such were mined and treated in Australia from the 1950's until 1971. Radium Hill, Rum Jungle in Northern Territory, and Mary Kathleen in Queensland were the producers of uranium (as yellowcake). The uranium was intended primarily for export to the United Kingdom and the United States for use in their weapons programs of the period, but much also was used in the production of electricity. With resumption of the mining and exporting of Australia's uranium in 1981, it has been sold strictly for electrical power generation with adequate safeguards in place to ensure this policy. Australia's uranium reserves are the world's largest having about 40% of the western world (Minerals Gazette, 1996b), and about 25% of the world total (Uranium Information Center Ltd., June 1998, Australia's uranium and who buys it, Nuclear issues briefing paper 1, accessed July 24, 1998, on the World Wide Web at the World Wide Web at URL <http://www.uic.com.au/nip01.htm>).

In October the Government granted approval for Energy Resources of Australia (ERA) to develop its Jabiluka Mine site on the edge of the World heritage-listed Kakadu National Park. The Jabiluka Mine was projected to produce 90,400 t of uranium oxide from 19.5 Mt of ore during a mine life of 28 years (U.S. Embassy, Canberra, Australia, 1997a). ERA's preferred option for development of the deposit was to have facilities occupying about 20 ha, with the ore trucked to ERA's Ranger operation 22 km away for processing. The haul road would be completely within ERA's leases, not within the boundaries of Kakadu National Park, and tailings would be placed in the completed Ranger pits (Resource Information Unit, 1998, p. 372).

### 8.3 Outlook

Because of a growing worldwide need for mineral and energy monthly, supplies which Australia is abundantly endowed and for which Australia was among the leaders in world supply, bauxite, coal, copper, diamond, gold, iron ore, lead, manganese, mineral sands, natural gas, and zinc, the country probably will continue to be a significant mineral supplier well into the 21st century.

Asia was an important export market for Australia's mineral resources. The Asian financial and economic crisis that manifested itself during 1997's last quarter was expected to slow Australia's economy, although the economy was still expected to grow at about a rate of 3.7% during 1998 (Far Eastern Economic Review, 1998).



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**AUSTRALIA: PRODUCTION OF MINERAL COMMODITIES 1/  
(for possible NW Tasmanian Carbonate Ore Application)  
(Metric tons unless otherwise specified)**

Commodity	1993	1994	1995	1996	1997 e/
<b>METALS</b>					
<b>Aluminum:</b>					
Bauxite, gross weight thousand tons					
	41,320	41,733	42,655	43,063 r/	44,465 2/
Alumina.	12,598	12,892	13,147	13,348 r/	13,385 2/
Metal, refined:					
Primary	1,381	1,317	1,297 r/	1,372 r/	1,495 2/
Secondary	34.8	55	55	95 r/	100 2/
<b>Copper:</b>					
Mine output, Cu content thousand tons					
	402	415	420	525	560 2/
Metal:					
Smelter:					
Primary	323	315	215	289	208 2/
Secondary e/	10	9.6	1.2	1.2	1.0
Refined:					
Primary thousand tons	285	312	242	314	271 2/
Secondary e/	24	24	18	24	24
<b>Gold:</b>					
Mine output, Au content kilograms					
	247,196	256,188	253,504	289,530 r/	311,740 2/
Metal:					
Refined:					
Primary	283,726	302,612	289,004	329,000	303,410 2/
Secondary	8,345	8,500 e/	8,747	3,620	780 2/
<b>Iron and Steel:</b>					
Iron ore: Gross weight thousand tons					
	120,534	128,493	142,936	147,100	157,766 2/
Fe content.	74,767	80,900 e/	88,653	93,000	97,901 2/
<b>Metal:</b>					
Pig iron.	7,414	7,466	7,476	7,774 r/	7,884 2/
Ferroalloys: e/					
Ferromanganese	75	100	110	110	95
Silicomanganese	75	100	100	95	95
Total	150	200	210	205	190
Steel, crude	7,853	8,424	8,447	8,415	8,769 2/
Semimanufactures e/	1.8 2/	4.0	4.0	4.0	5.0
<b>Nickel:</b>					
Mine output, Ni content	65	79	98	113	124 2/
Metal, smelter (refined Ni and Ni content of oxide)					
	55	67	77	74	74 2/
<b>Silver:</b>					
Mine output, Ag content	1.1	1.0	0.94	1.01 r/	1.106 2/
Metal, refined	0.345	0.362	0.346	0.356	0.280 2/
<b>INDUSTRIAL MINERALS</b>					
Lime e/ (thousand tons)	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000



**HATCH**

**AUSTRALIA: PRODUCTION OF MINERAL COMMODITIES 1/  
(for possible NW Tasmanian Carbonate Ore Application)  
(Metric tons unless otherwise specified)**

Commodity	1993	1994	1995	1996	1997 e/
Magnesite	260,600 e/	285,610	263,249	237,707 r/	245,127 2/
Dolomite	10,000	10,000	10,000	10,000	10,000
<b>Limestone:</b>					
For cement	6,000	6,000	6,000	6,000	6,000
For other uses	6,000	6,000	6,000	6,000	6,000
<b>Other:</b>					
Crushed and broken stone	65,000	65,000	65,000	65,000	65,000
Dimension stone	100	100	100	100	100
Unspecified	30,000	30,000	30,000	30,000	30,000

**MINERAL FUELS AND RELATED MATERIALS**

**Coal:**

Bituminous and subbituminous thousand tons

	226,330	227,772	193,500	199,800	216,490 2/
Lignite	48,458	48,582	50,700	53,600	60,100
Total	274,788	276,354	244,200	253,400	276,590
Coke, metallurgical e/	300	300	322	325	325
Fuel briquettes e/	750	750	750	750	750

**Uranium:**

mine output, U content	2.26	2.21	3.7	4.95	5.5 2/
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e/ Estimated. r/ Revised.

1/ Includes data available through August 5, 1998.

2/ Reported figure.

3/ Excludes tin content of copper-tin and tin-tungsten concentrates.

4/ In addition, about 7,000 metric tons per year of sillimanite clay, also known as kaolinized sillimanite, containing 40% to 48% aluminum oxide, is produced.

**AUSTRALIA: STRUCTURE OF THE MINERAL INDUSTRY IN 1997  
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(Thousand metric tons unless otherwise specified)**

Major Operating Companies	Location	Capacity e/
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
<b>Alumina</b>		
Queensland Alumina Ltd., operator [Comalco Ltd., 30.3%; Kaiser Aluminum And Chemical Corp. (Australia) Ltd., 28.3%; Alcan Australia Ltd., 21.4%; and Pechiney Australia Pty. Ltd., 20%]	Gladstone Refinery, QLD	3,000
Nabalco Pty. Ltd., operator. (Swiss Aluminium Australia Ltd., 70%; And Gove Aluminium Ltd., 30%)	Gove Refinery, NT	1,600

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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
Alcoa of Australia Ltd., 100%	Kwinana Refinery, WA	1,900
Alcoa of Australia Ltd., 100%	Pinjarra Refinery, WA	3,000
Alcoa of Australia Ltd., 100%	Wagerup Refinery, WA	1,700
Worsley Alumina Pty. Ltd., operator [Reynolds Australia Alumina Ltd., 56%; Billiton Australia Pty. Ltd., 30%; Kobe Alumina Associates (Australia) Pty. Ltd., 10%; And Nissholwai Alumina, 4.0%]	Worsley Refinery, WA	1,600
<b>Aluminum Metal:</b>		
Comalco Aluminium (Bell Bay) Ltd., 100%	Bell Bay Smelter, TAS	120
Boyne Island Smelters Ltd., operator (Comalco Ltd., 59.25%; Marubeni Corp., Sumitomo Corp., and Light Metal Industries, 17% collectively; Mitsubishi Corp. and Mitsubishi Materials Corp., 14.25% Jointly; and Yoshida Kogyo KK, 9.5%)	Boyne Island Smelter, QLD	230
Capral Aluminium Ltd., 100%	Kurri Kurri Smelter, NSW	150
Alcoa of Australia Ltd., 100%	Point Henry Smelter, VIC	182
Alcoa of Australia Ltd., 45% and Manager; ALUVIC (State of VIC agency), 25%; First National Resources Trust, 10%; China International Trust Investment Co., 10%; and Marubeni, 10%	Portland Island Smelter, VIC	327
Tomago Aluminium Co. Pty. Ltd., Operator. (Gove Aluminium Finance Ltd., 35%; Pechiney Australia Pty. Ltd., 35%; Australian Mutual Provident Society, 15%; VAW Australia Pty. Ltd., 12%; and Hunter Douglas Ltd., 3%)	Tomago Smelter, NSW	380
<b>Bauxite:</b>		
Nabalco Pty. Ltd., manager. (Swiss Aluminium Australia Ltd., 70%; And Gove Aluminium Ltd., 30%)	Gove surface mine, NT	7,000
Alcoa of Australia Ltd., 100%	Huntly, Jarrahdale, and Williowdale surface mines, WA	24,000 2/



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<b>Major Operating Companies</b>	<b>Location</b>	
<b>Commodity and Major Equity Owners</b>	<b>Main Facilities 1/</b>	<b>Capacity e/</b>
Worsley Alumina Pty. Ltd., manager [Reynolds Australia Alumina Ltd., 56%; Billiton Australia Pty. Ltd., 30%; Kobe mines, WA Alumina Associates (Australia) Pty. Ltd., 10%; and Nissho Iwai Australia Ltd., 4.0%]	Mount Saddleback and Worsley surface	5,000
Comalco Aluminium Ltd., 100%	Weipa surface mine, QLD	11,000
<b>Cement:</b>		
Blue Circle Southern Cement Ltd., 100%	Berrima Plant, NSW	1,200
Adelaide Brighton Cement Ltd., 100%	Birkenhead Plant, SA	1,000
Queensland Cement Ltd., 100%	Darra Plant, QLD	700
Adelaide Brighton Cement Ltd., 100%	Geelong Plant, VIC	800
Goliath Cement Holdings Ltd., 100%	Railton Plant, TAS	1,000
Cockburn Cement Ltd., 100%	South Coogee Plant, WA	1,000
<b>Coal, Black:</b>		
Powercoal Pty. Ltd., 100%	Angus Place underground mine, NSW	2,000
BHP Steel (AIS) Pty. Ltd., 100%	Appin underground mine, NSW	2,400
Coalex Pty. Ltd., 95% and manager;	Baal Bone underground mine, NSW and Sumisho Coal Development Pty. Ltd., 5%	3,500
Coal Operations Australia Ltd., 78.3% And manager; Nippon Oil (Australia) Pty. Ltd., 8.7%; Nippon Steel Australia Pty. Ltd., 8%; and KEPCO Resources Australia Pty. Ltd., 5%	Baywater No. 2 open cut, NSW	4,000
Coal Operations Australia Ltd., 78.3% And manager; Nippon Oil (Australia) Pty. Ltd., 8.7%; Nippon Steel Australia Pty. Ltd., 8%; and KEPCO Resources Australia Pty. Ltd., 5%	Baywater No.3 open cut, NSW	4,000
Central Queensland Coal Associates, 100% (BHP Coal Pty. Ltd., 52.1%; QCT Resources	Blackwater open cut, QLD	5,000

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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
Ltd., 32.37%; and Mitsubishi Development Pty. Ltd., 15.53%		
Queensland Coal Pty. Ltd., 57.195% and Manager; ARCO Coal Australia Inc., 17.527%; ARCO Resources Ltd., 13.89%; EPDC (Australia) Pty. Ltd., 7.972%; and Japan Coal Development Co. Ltd., 3.416%	Blair Athol open cut, QLD	8,500
Bloomfield Collieries Pty. Ltd., 100%	Bloomfield open cut, NSW	2,000
Shell Coal (Callide) Pty. Ltd., 66.7% and Manager; and AMP Society Ltd., 33.3%	Boundary Hill open cut, QLD	3,500
Shell Coal (Callide) Pty. Ltd., 66.7% and Manager; and AMP Society Ltd., 33.3%	Callide open cut, QLD	3,500
Thiess Contractors Pty. Ltd, 5% and operator, And Portman Mining Ltd., 95%	Burton open-cut, QLD	4,000
Camberwell Coal Pty. Ltd., manager [Navidale Pty. Ltd., 50%; Toyota Tsusho Mining (Australia), 40%; and Dia Coal Mining (Australia) Pty. Ltd., 10%]	Camberwell open cut, NSW	4,000
Coalex Pty. Ltd., 80% and manager; Japan	Clarence underground mine, NSW Energy Australia (Pty. Ltd., 10%; and Yukong Ltd. (Republic of Korea), 10%	2,500
Collinsville Coal Co. Pty. Ltd., 75% and	Collinsville open-cut/ underground manager; and Itochu Coal Resource of mine, 25% QLD Australia Pty. Ltd.	2,000
Powercoal Pty. Ltd., 100%	Cooranbong underground mine	1,600
BHP Steel (AIS) Pty. Ltd., 100%	Cordeaux underground mine NSW	2,800
Cumnock No. 1 Colliery Pty. Ltd., 100%	Cumnock No. 1 underground mine, NSW	2,500
ARCO Coal Australia Inc., 87% and	Curragh open cut, QLD	6,600



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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
Manager; and Mitsui Coal Development Australia Pty. Ltd., 13%		
Shell Coal (Drayton) Pty. Ltd., 74.8% And manager; AMP Society Ltd., 13.4%; Mitsui Coal Development Australia Pty. Ltd., 3.8%; Mitsui Mining (Australia) Pty. Ltd., 3%; Daesung (Australia) Pty. Ltd., 2.5%; and Hyundai (Australia) Pty. Ltd., 2.5%	Drayton open cut, NSW	4,000
Ebenezer Mining Co., 100%	Ebenezer open cut, QLD	3,000
BHP Steel (AIS) Pty. Ltd., 100%	Elouera underground mine, NSW	2,500
Capricorn Coal Management Pty. Ltd., 100%. [Shell Coal German Holdings (Australia) Ltd., 46.75%; Tigor Ltd., 26.06%; British mine, QLD British Coal Corp., 14.81%; And Ruhrkohle Australia Pty. Ltd., 12.38%]	Creek open-cut/underground	3,500
Capricorn Coal Management Pty. Ltd., Underground 100%. [Shell Coal German (German Creek) Mine, QLD Pty. Ltd., 59.47%; Tigor Energy Pty. Ltd., 31.14%; And Marubeni Australia Pty. Ltd., 9.39%]	Creek East open-cut/	3,500
Central Queensland Coal Associates, 100% (BHP Coal Pty Ltd., 52.1%; QCT Resources Ltd., 32.37%; and Mitsubishi Development Pty. Ltd., 15.53%)	Goonyella open cut, QLD	9,250
Gordonstone Coal Management Pty. Ltd., Mine, 100% (ARCO Coal Australia Inc., 50%; ARCO Resources Ltd., 30%; Mitsui Gordonstone Investment Pty. Ltd., 15%; and MCL Coal Investment Pty. Ltd., 5%)	Gordonstone underground, QLD	4,600
BHP Minerals Ltd., 64.14% and Manager; QCT Resources Ltd., 32.37%; and Mitsubishi Development Pty. Ltd., 3.49%	Gregory open cut, QLD	3,500
Newcastle Wallsend Coal Co. Pty. Ltd., 100%	Gretley underground mine, NSW	1,500



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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
Novacoal Australia Pty. Ltd., 60% and manager and Mitsubishi Coal Development Pty. Ltd., 40%	Howick open cut, NSW	5,000
Coal and Allied Industries Ltd., 100%	Hunter Valley No. 1 open cut, NSW	6,300
Optima Energy, 100%	Leigh Creek open cut, SA	3,000
Exxon Coal and Minerals Australia Ltd., 100%	Lemington open cut, NSW	4,000
Liddell Coal Operations Pty. Ltd., Manager. (Savage Resources Ltd., 67.5%; and Mitsui Matsushima Australia Pty. Ltd., 32.5%)	Liddell open cut, NSW	4,000
Rio Tinto Coal (NSW) Pty. Ltd., Manager. Coal and Allied Mount Industries Ltd., 80%, and Pohang Steel Australia Pty. Ltd., 20%	Thorley open cut, NSW	6,500
BHP Coal Pty. Ltd., 80%, and BHP Mitsui Coal Pty. Ltd., 20%	Moura open cut, QLD	5,000
Muswellbrook Coal Co. Ltd., 100%	Muswellbrook No. 2 open-cut/ underground mine, NSW	1,850
The Griffin Coal Mining Co. Pty. Ltd., 100%	Muja open cut, WA	2,500
Powercoal Pty. Ltd., 100%	Myuna underground mine, NSW	1,500
Newlands Coal Pty. Ltd., 75% and manager; And Itochu Resources of Australia Pty. Ltd., 25%	Newlands open-cut/underground mine, QLD	5,000
Muswellbrook Coal Co. Ltd., 100%	Muswellbrook No. 2 open-cut /underground mine, NSW	1,850
The Griffin Coal Mining Co. Pty. Ltd., 100%	Muja open cut, WA	2,500
Powercoal Pty. Ltd., 100%	Myuna underground mine, NSW	1,500
Newlands Coal Pty. Ltd., 75% and manager;	Newlands open-cut/ underground and Itochu Resources of Australia Pty. Ltd., 25% mine, QLD	5,000



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<b>Major Operating Companies</b>	<b>Location</b>	
<b>Commodity and Major Equity Owners</b>	<b>Main Facilities 1/</b>	<b>Capacity e/</b>
Powercoal Pty. Ltd., 100%	Newstan underground mine, NSW	2,500
White Mining Ltd., 51% and manager; and Sumisho Coal Development Pty. Ltd., 49%	North Goonyella underground mine, QLD	3,000
Central Queensland Coal Associates, 100%. (BHP Coal Pty. Ltd., 52.1%; QCT Resources Ltd., 32.37%; and Mitsubishi Development Pty. Ltd., 15.53%	Norwich Park open cut, QLD	4,500
Oaky Creek Coal Pty. Ltd., 75%,  Australia Pty. Ltd., 15%, and Itochi Coal mine, QLD Resources of Australia Pty. Ltd., 10%	Oaky Creek open-cut/ underground operator and manager, Sumitomo Coal	3,500
Central Queensland Coal Associates, 100% (BHP Coal Pty Ltd., 52.1%; QCT Resources Ltd., 32.37%; and Mitsubishi Development Pty. Ltd., 15.53%	Peak Downs open cut, QLD	7,000
Wesfarmers Coal Ltd., 100%	Premier open cut, WA	3,000
Peabody Resources Ltd., 100% at Ravensworth and 50% at Narama RGC Ltd., 50% at Narama	Ravensworth-Narama open cut, NSW	6,200
BHP Coal Pty. Ltd., 80%, and BHP Mitsui Coal Pty. Ltd., 20%	Riverside open cut, QLD	6,000
Central Queensland Coal Associates, 100% (BHP Coal Pty. Ltd., 52.1%; QCT Resources Ltd., 32.37%; and Mitsubishi Development Pty. Ltd., 15.53%	Saraji open cut, QLD	5,000
Bulga Coal Management Pty. Ltd.,  Australia Pty. Ltd., 10% mine, NSW	Saxonville-Bulga 90% and manager; and Nippon Steel open-cut/underground	9,000
Cyprus Springvale Ltd., 50% and manager; And Samsung Development (Australia) Pty. Ltd., 50%	Springvale underground mine, NSW	2,000
Austral Coal Ltd., 100%	Tahmoor underground mine, NSW	4,100



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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
Oceanic Coal Australia Ltd., 80% and Manager; Marubeni Coal Pty. Ltd., 14%; Chelsea Coal Pty. Ltd., 3%; and Kokan Kogyo (Australia) Pty. Ltd., 3%	Teralba underground mine, NSW	1,700
BHP Steel (AIS) Pty. Ltd., 100%	Tower underground mine, NSW	1,600
Ulan Coal Mines Ltd., manager (Mitsubishi Development Pty. Ltd., 49%; Exxon Coal Australia Ltd., 36%; and Axiom Funds Management Ltd., 15%)	Ulan open cut-underground mine, NSW	5,500
Wambo Mining Corp. Pty. Ltd., 100%	Wambo open-cut/underground mine, NSW	4,000
Peabody Resources Ltd., 28.75% and Manager. (Mitsubishi Coal Development Pty. Ltd., 22.75%; Ticor Energy Pty. Ltd., 20%; Peabody Australia Pty. Ltd., 15%; Nippon Steel Australia Pty. Ltd., 7.5%; and Mitsubishi Materials (Australia) Pty. Ltd., 6%	Warkworth open cut, NSW	5,000
BHP Steel (AIS) Pty. Ltd., 100%	West Cliff underground mine, MSW	3,000
Oceanic Coal Australia Ltd., 80% and Manager; Marubeni Coal Pty. Ltd., 14%; Chelsea Coal Pty. Ltd., 3%; and Kokan Kogyo (Australia) Pty. Ltd., 3%	West Wallsend underground mine, NSW	2,400
Powercoal Pty. Ltd., 100%	Wyee underground mine, NSW	1,800
Coal, brown Hazelwood Power Corp., 100%	Hazelwood open cut, VIC	13,000
Loy Yang Power Ltd., 100%	Loy Yang open cut, VIC	27,000
Yallourn Energy Pty. Ltd., manager (Powergen International, 49.9%; AMP Society Ltd., 26%; Itochu Australia Ltd., 10.4%; Axiom Funds Management Ltd., 8%; and Hastings Fund Management, 5.7%	Yallourn open cut, VIC	18,000



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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
<b>Copper</b>		
Worsley Alumina Pty. Ltd., manager  (Normandy Gold Ltd., 44.45%; Acacia Resources Ltd., 33.33%; and Newcrest mine, WA Mining Ltd., 22.22%)	Boddington open-cut/ Underground	10
Ernest Henry Mining Pty. Ltd., operator  And manager. (MIM Holdings Ltd., 51%, And Savage Resources Ltd., 49%)	Ernest Henry open-cut, Queensland	95
Girilambone Copper Co. Pty. Ltd., Manager. Straits Resources Ltd., 60%; and Nord Pacific Ltd., 40%	Girilambone open cut, NSW	15
Murchison Zinc Co. Pty. Ltd., 100%	Golden Grove (includes Gossan 50 Gossan Hill and Scuddles) underground mine	50
Aberfoyle Ltd., 100%	Gunpowder-Mammoth open cut mine, QLD	45
Aberfoyle Ltd., 100%	Hellyer underground mine, TAS	4
MIM Holdings Ltd., 100%	Hilton underground mine, QLD	180
Murchison United NL, 60% and manager;	Mount Cuthbert open cut mine, QLD and Brancote Australia NL, 40%	8
MIM Holdings Ltd., 100%	Mount Isa underground mine, QLD	150
MIM Holdings Ltd., 100%	Mount Isa Smelter, QLD	175
Copper Mines of Tasmania Pty. Ltd., 100%	Mount Lyell underground mine, TAS	20
WMC Ltd., 100%	Nifty open cut, WA	10
North Ltd., 80% and operator; Sumitomo	Northparkes open-cut/ Underground	40
Metal Mining Oceania Pty. Ltd., 13.3%; and SC Mineral Resources mine, NSW Pty. Ltd., 6.7%		

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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
Olympic Dam Operations Pty. Ltd., manager (WMC Ltd., 100%)	Olympic Dam underground mine, SA	85
Olympic Dam Operations Pty. Ltd., manager (WMC Ltd., 100%)	Olympic Dam Refinery, SA	50
Olympic Dam Operations Pty. Ltd., manager (WMC Ltd., 100%)	Olympic Dam Smelter, SA	70
Placer Pacific Ltd., 100%	Osborne underground mine, QLD	50
Peak Gold Mines Pty. Ltd., 100%	Peak underground mine, NSW	3
Furukawa Co. Ltd., 52.5%; Nittetsu Mining Co., 20%; Nissho Iwai Corp., 17.5%; Itochu Corp., 10%	Port Kembla Refinery, NSW	80
Furukawa Co. Ltd., 52.5%; Nittetsu Mining Co., 20%; Nissho Iwai Corp., 17.5%; Itochu Corp., 10%	Port Kembla Smelter, NSW	80
Pasminco Ltd., 100%	Rosebery underground mine, TAS	4
Australian Resources Ltd., 100%	Selwyn open-cut/underground mine, QLD	16
Normandy Gold Ltd., 100%	Tennant Creek open-cut/underground mines, NT	17
RGC Ltd., 100%	Thalanga underground mine, QLD	28
Copper Refineries Pty. Ltd., operator (MIM Ltd., 100%)	Townsville Refinery, QLD	175
Denehurst Ltd., 100%	Woodlawn underground mine, NSW	8
<b>Gold</b> WMC Ltd., 100%	Agnew open cut-underground mine, WA	4,000
Normandy Mining Ltd., 70% and	Big Bell Consolidated (includes former manager; Saint Barbara	7,000



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Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
	Mines Ltd., 30%) Golden Crown) open-cut/underground mine, WA	
Saint Barbara Mines Ltd., 100%	Bluebird open cut, WA	4,000
Worsley Alumina Pty. Ltd., Manager. (Normandy Gold Ltd., 44.45%; Acacia Resources Ltd., 33.33%; and Newcrest Mining Ltd., 22.22%)	Boddington open-cut/underground mine, WA	12,000
Great Central Mines Ltd., 100%	Bronzewing open-cut/underground mine, WA	6,200
Herald Resources Ltd., 100%	Coolgardie open-cut/underground operations, WA	4,000
Ernest Henry Mining Pty. Ltd., operator and manager. (MIM Holdings Ltd., 51%, and Savage Resources Ltd., 49%)	Ernest Henry open cut, Queensland	4,000
Normandy NFM Ltd., 100%	Granites-Dead Bullock Soak open-cut/underground mines, NT	7,000
Placer (Granny Smith) Pty. Ltd., manager (Placer Pacific Ltd., 60%; and Delta Gold NL, 40%)	Granny Smith open cut, WA	4,800
Alcoa of Australia Ltd., 100%	Hedges open cut, WA	4,900
Goldfields Ltd., 100%	Henty underground mine, TAS	2,800
Hill 50 Gold NL, 100%	Hill 50 open-cut/underground mine, WA	4,000
Great Central Mines Ltd., 100%	Jundee open cut, WA	6,600
Australian Gold Refineries, 100% (State of WA agency)	Kalgoorlie Refinery, WA	46,000
North Ltd., manager, 50%; and Delta Gold NL, 50%	Kanowna Belle open-cut/underground mine, WA	5,300



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<b>Major Operating Companies</b>	<b>Location</b>	
<b>Commodity and Major Equity Owners</b>	<b>Main Facilities 1/</b>	<b>Capacity e/</b>
Kidston Gold Mines Ltd., 100%	Kidston open cut, QLD	6,500
Sons of Gwalia Ltd., 100%	Marvel Loch-Southern Cross open-cut/underground mines, WA	3,000
Kalgoorlie Consolidated Gold Mines Pty. Ltd., manager(Homestake Gold of Australia Ltd., 50%; and Gold Mines of Kalgoorlie Ltd., 50%)	Mount Charlotte underground mine, WA	4,300
Normandy Mount Leyshon Ltd., 100%	Mount Leyshon open cut, QLD	7,500
Australian Resources Ltd., 100%	Mount McClure open-cut/underground mine, WA	3,100
Eagle Mining Corp. NL, 100%	Nimary open cut, WA	3,600
Central Norseman Gold Corp. Ltd., 100%	Norseman open-cut/underground mine, WA	3,700
North Ltd., 80% and operator; Sumitomo Metal Mining Oceania Pty. Ltd., 13.3%; and SC Mineral Resources Pty. Ltd., 6.7%	Northparkes open-cut/underground mine, NSW	2,500
Olympic Dam Operations Pty. Ltd., manager (WMC Ltd., 100%)	Olympic Dam underground mine, SA	1,500
MIM Ltd., 100%	Pacific precious metals refinery, NSW	1,900
Goldfields Kalgoorlie Ltd., 100% and manager	Paddington open cut, WA	4,100
Peak Gold Mines Pty. Ltd., 100%	Peak underground mine, NSW	4,700
Australian Gold Refineries, 100% (State of WA agency)	Perth Refinery (Newburn), WA	95,000
Plutonic Resources Ltd., 100%	Plutonic open-cut/underground mine, WA	5,800
Carpentaria Gold Pty. Ltd., 50.1% and manager; and Haoma Mining NL, 49.9%	Ravenswood open cut, QLD	-
WMC Ltd., 100%	Saint Ives open-cut/underground mine, WA	7,500



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<b>Major Operating Companies</b>	<b>Location</b>	
<b>Commodity and Major Equity Owners</b>	<b>Main Facilities 1/</b>	<b>Capacity e/</b>
Sons of Gwalia Ltd., 100%	Sons of Gwalia open cut, WA	4,000
MPI Gold Pty. Ltd., 50% and Stawell Gold Mines Pty. Ltd., 50%	Stawell underground mine, VIC	2,700
Kalgoorlie Consolidated Gold Mines Pty. Ltd., manager.(Homestake Gold of Australia Ltd., 50%; and Gold Mines of Kalgoorlie Ltd., 50%)	Super Pit (includes Fimiston) operation, WA	22,000
Otter Gold Mines Ltd., 60% and manager; and Acacia Resources Ltd., 40%	Tanami open cut, NT	4,000
Newcrest Mining Ltd., 100%	Telfer open-cut/underground mine, WA	12,000
Normandy Gold Ltd., 100%	Tennant Creek open-cut/underground mines, NT	4,000
Wiluna Mines Ltd., 100%	Wiluna open-cut/underground mine, WA	3,300
Sons of Gwalia Ltd., 70% and manager; Coeur D'alene Mines Corp. 25%; and Gemini Mining Pty. Ltd., 5%	Yilgarn Star open-cut/underground mine, WA	3,400
<b>Steel</b>		
BHP Steel Ltd., 100%	Newcastle steelworks, NSW	1,800
BHP Steel Ltd., 100%	Port Kembla steelworks, NSW	4,000
BHP Steel Ltd., 100%	Sydney (Rooty Hill) mini mill, NSW	250
BHP Steel Ltd., 100%	Whyalla steelworks, SA	1,200
<b>Iron ore</b>		
Hamersley Iron Pty. Ltd., 100%	Brockman No. 2 Detrital open cut, WA	4,500
Hamersley Iron Pty. Ltd., 60% and manager, and Steel Industry and Trade Group Corp., 40%, a People's Republic of China Government Agency	China Iron Channar open cut, WA	8,000



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**(Thousand metric tons unless otherwise specified)**

<b>Major Operating Companies</b>	<b>Location</b>	<b>Capacity e/</b>
<b>Commodity and Major Equity Owners</b>	<b>Main Facilities 1/</b>	
BHP Iron Ore Pty. Ltd., 85% and manager; CI Minerals Australia Pty. Ltd., 8%; and Mitsui Iron Ore Corp. Pty. Ltd., 7% Shay Gap, and Sunrise Hill), WA	Goldsworthy open cut	8,000
BHP Iron Ore Pty. Ltd., 100%	Jimblebar open cut, WA	3,000
Koolyanobbing Iron Pty. Ltd., manager. (Portman Resources NL, 60%, and Angang Australia Pty. Ltd., 40%)	Koolyanobbing open cut, WA	2,000
Hamersley Iron Pty. Ltd., 100%	Marandoo open cut, WA	12,000
BHP Iron Ore Pty. Ltd., 85% and manager; Mitsui Itochu Iron Pty. Ltd., 10%; and CI Minerals Australia Pty. Ltd., 5% Orebody 23-25, Orebody 29, and Yarrie) open cut, WA	Mount Newman (includes, Whaleback	35,000
Hamersley Iron Pty. Ltd., 100% Robe River Iron Associates, manager. (Robe River Mining Co. Pty Ltd., 53%; Mitsui Iron Ore Development Pty. Ltd., 33%; Nippon Steel Australia Pty. Ltd., 10.5%; and Sumitomo Metal Australia Pty. Ltd., 3.5%	Mount Tom Price open cut, WA Pannawonica-Deepdale (includes Mesa J) open cut, WA	28,000 32,000
Hamersley Iron Pty. Ltd., 100%	Paraburdoo open cut, WA	15,000
Goldamere Pty. Ltd., 100%	Savage River open cut, TAS	1,500
BHP Iron Ore Pty. Ltd., manager. (BHP Minerals Pty. Ltd., 55%; Pilbara Iron Pty. Ltd., 30%; CI Minerals Australia Pty. Ltd., 8%; and Mitsui Iron Ore Corp. Pty. Ltd., 7%)	Yandi open cut, WA	25,000
<b>Nickel</b>		
Outokumpu Mining Australia Pty. Ltd., 100%	Forrestania underground mines (2), 375 kilometers southeast of Perth, WA	10
WMC Ltd., 100%	Kalgoorlie Smelter, WA	80
WMC Ltd., 100%	Kambalda Nickel Operations, WA	35



**HATCH**

**AUSTRALIA: STRUCTURE OF THE MINERAL INDUSTRY IN 1997**  
(for possible NW Tasmanian Carbonate Ore Application)  
(Thousand metric tons unless otherwise specified)

Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
WMC Ltd., 100%	Kwinana Refinery, WA	42
WMC Ltd., 100%	Leinster Nickel Operations, WA	30
WMC Ltd., 100%	Mount Keith Mine, WA	37
QNI Ltd., 100%	Yabulu Refinery, QLD	30
<b>Silver</b>		
Pasminco Ltd., 100%	Broken Hill open-cut/ underground (South) mine, NSW	120,000
BHP Minerals Ltd., 100%	Cannington underground mine, Queensland	750,000
Cobar Mines Pty. Ltd., 100%	Cobar (GSM) underground mine, NSW	5,000
Pasminco Ltd., 100%	Elura underground mine, NSW	45,000
McArthur River Mining Pty. Ltd., operator (Mount Isa Mines Ltd., 70%; and ANT Minerals Pty. Ltd. holding the combined Japanese interests of Nippon Mining and Metals Co. Ltd., 15%; Mitsubishi Materials Corp., 5%; Mitsui & Co. Ltd., 5%; and Marubeni Corp., 5%)	McArthur River underground mine, NT	18,000
Mount Isa Mines Ltd., 100%	Mount Isa underground mine, QLD	375,000
Olympic Dam Operations Pty. Ltd., manager. (WMC Ltd., 100%)	Olympic Dam underground mine, SA	12,900
Peak Gold Mines Pty. Ltd., 100%	Peak underground mine, NSW	20,000
Pasminco Ltd., 100%	Rosebery underground mine, TAS	20,000
Normandy Mining Co. Ltd., 100%	Woodcutters underground mine, NT	55,000
Denehurst Ltd., 100%	Woodlawn underground mine, NSW	4,500



**HATCH**

**AUSTRALIA: STRUCTURE OF THE MINERAL INDUSTRY IN 1997**  
 (for possible NW Tasmanian Carbonate Ore Application)  
 (Thousand metric tons unless otherwise specified)

Major Operating Companies	Location	
Commodity and Major Equity Owners	Main Facilities 1/	Capacity e/
<b>Uranium</b>		
Olympic Dam Operations Pty. Ltd., manager. (WMC Ltd., 100%)	Olympic Dam underground mine, SA	1,500
Energy Resources of Australia Ltd., 100%	Ranger open cut, NT	4,500

**References Cited:**

A.P. Green Industries Inc., 1998, A.P. Green Industries reports improved fourth quarter and year-end results: Mexico, MO, A.P. Green Industries Inc. press release, February 12, 3 p.

Dravo Lime Co., 1998, Dravo Lime Co. annual report 1997: Dravo Lime Co., 38 p.

Sorbalit--Specialized flue gas treatment technology for controlling acid gas, mercury and dioxin emissions: Dravo Lime Co. product brochure, 8 p.

Gajardo, Anibal, 1997, Cement, gypsum & lime in Chile--An expanding market for the future, *in* The 2nd Industrial Minerals North American Annual Meeting, Cancun, Mexico, 1997, Proceedings: London, U.K., Industrial Minerals magazine, [unpaginated].

Global Stone Corp., 1997, Global Stone reports operational developments: Global Stone Corp. press release, September 12, 1 p.

Industrial Minerals, 1997a, Carmeuse invests in limestone/lime joint ventures: Industrial Minerals, no. 358, July, p. 14.

1997b, Magnesia/lime merger as Calceed joins Ube: Industrial Minerals, no. 356, May, p. 15.

National Lime Association, 1998, Chemical Lime acquires Natividad plant: *Limelites*, v. 64, no. 3, p. 1.

North American Mineral News, 1997a, Medusa buys Lee Lime Corp.: North American Mineral News, no. 30, November, p. 5.

1997b, Phosphate recovery project progress: North American Mineral News, no. 28, September, p. 16.

1998a, Marietta expands lime to 850,000 s.tpa at Woodville: North American Mineral News, no. 32, January, p. 6.

1998b, [Untitled]: North American Mineral News, June, no. 37, p. 16.

Paint and Coatings Industry, 1997, Development of lime paint offers new weapon in Antimicrobial arsenal: *Paint and Coatings Industry*, v. 13, no. 10, p. 216-217.



## HATCH

### References Cited:

Rock Products, 1997, United States Lime & Minerals agrees to sell Corson Lime: Rock Products, v. 100, no. 5, p. 7.

1998, Marblehead Lime completes upgrade: Rock Products, v. 101, no. 3, p. 5

Sommer, Ron, 1997, News from Dravo Corporation: Pittsburgh, PA, Dravo Lime Co. press release, July 2, 2 p.

United Nations Climate Change Secretariat, 1998, Report of the conference of the parties on its third session, held at Kyoto from 1 to 11 December 1997: Bonn, United Nations Climate Change Secretariat, 60 p.

United States Lime & Minerals Inc., 1998, U.S. Lime & Minerals annual report 1997: U.S. Lime & Minerals Inc., 163 p.

World Cement, 1997a, Major investment boosts Cockburn's quicklime operations: World Cement, v. 28, no. 8, p. 36-37.

1997b, World Cements annual review 1997: World Cement, v. 28, no. 7, p. 44

Lime. Ch. in Mineral Commodity Summaries, annual.1

Lime. Ch. in Minerals Yearbook, annual.1

Limestone and dolomite. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Aggregates Manager, 1997, Martin Marietta to buy American Aggregates: Aggregates Manager, v. 1, no. 11, p. 11.

Pit & Quarry, 1997, Martin Marietta buys four more: Pit & Quarry, v. 89, no. 12, p. 6

1997b, Vulcan acquires Georgia, Texas quarries: Pit & Quarry, v. 90, no. 6, p. 6.

1997c, Vulcan buys Arkansas quarry: Pit & Quarry, v. 90, no. 1, p. 9.

Rock Products, 1997, British aggregate companies continue to expand in North America: Rock Products, v. 100, no. 5, p. 7.

1997b, Benchmark reorganizes into three regions: Rock Products, v. 100, no. 9, p. 7.

1997c, Vulcan acquires Georgia and Texas quarries: Rock Products, v. 100, no. 12, p. 7.

1998, Redland accepts \$3 billion acquisition bid from Lafarge: Rock Products, v. 101, no. 1, p. 5.

### Other:

Construction stone. Ch. in United States mineral resources.

U.S. Geological Survey Professional Paper 820, 1973.

Limestone and dolomite. Ch. in United States mineral resources. U.S. Geological Survey Professional Paper 820, 1973.



## HATCH

### References Cited:

- Natural aggregate—Building America's future. U.S. Geological Survey Circular 1110, 1993.
- Natural aggregates of the conterminous United States, U.S. Geological Survey Bulletin, 1594, 1988.
- Chemical Economics Handbook, SRI International.
- Chemical Market Reporter.
- Chemistry and Technology of Lime and Limestone, John Wiley & Sons, 1980.
- Industrial Minerals (London).
- Industrial Minerals and Rocks, 6th ed., AIME, 1994.
- Industrial Specialty News.
- Lime. Ch. in Mineral facts and problems, U.S. Bureau of Mines Bulletin 675, 1985.
- Lime and Limestone: Chemistry and Technology, Production and Uses, Wiley-VCH, 1998.
- Pit and Quarry.
- Rock Products.
- 1 Prior to January 1996, published by the U.S. Bureau of Mines.
- Alcoa of Australia Ltd., 1997, Annual report: Alcoa of Australia Ltd., 41 p.
- Ashton Mining Ltd., 1997a, Annual report: Ashton Mining Ltd., 58 p.
- 1997b, Attachment to Preliminary final statement for year ended 31 December 1997: Ashton Mining Ltd., p. 1-4.
- 1997c, Quarterly report to 31 December 1997: Ashton Mining Ltd., p. 1
- Australian Bureau of Agricultural and Resource Economics, 1998, Australian mineral statistics—March quarter: Australian Bureau of Agricultural and Resource Economics, 32 p.
- Bachman, David, 1997, Western Australian iron ore industry review - An overview of iron ore industry developments: Perth, Western Australia Department of Resources Development, 64 p.
- Bureau of Resource Sciences, 1998, Australian petroleum exploration and development activity 1 October to 31 December 1997: Canberra, Bureau of Resource Sciences, 4 p.
- Coal Age, 1997a, Arco considers a withdrawal from coal business: Coal Age, v. 102, no. 5, p. 10.
- 1997b, International Longwall—Australia: Coal Age, v. 102, no. 9, p. 29.
- 1997c, News—Australia: Coal Age, v. 102, no. 10, p. 13.

## HATCH

### References Cited:

Comalco Ltd., 1997, Annual report: Comalco Ltd., 80 p.

Edwards, G.E., 1997, Australia—Responding to the Asian challenge: Coaltrans 97 Conference, Istanbul, October 13-15, 1997, p. 93-108.

Far Eastern Economic Review, 1998, Economic indicators—Selected Asian countries:

Far Eastern Economic Review, v. 161, no. 4, January 22, p. 58.

Fertilizer Week, 1997, Queensland fert project moves forward: Fertilizer Week, v. 11, no. 25, November 3, p. 1-2.

Gwalia Consolidated Ltd., 1997, Annual report: Gwalia Consolidated Ltd., 72 p.  
1997f, World of minerals—Headline news: Industrial Minerals, no. 359, August, p. 8.  
1998a, Australia—The Asia connection: Industrial Minerals, no. 364, January, p. 39.

Metal Bulletin, 1997a, Construction of Townsville smelter on schedule: Metals Bulletin, no. 8239, December 22, p. 7.

1997b, Worsley to expand alumina refinery: Metals Bulletin, no. 8210, September 11, p. 5.

1998a, Hamersley remains optimistic about Asia: Metals Bulletin, no. 8167, April 6, p. 24.

1998b, Iron and steel—China still world's largest producer: Metals Bulletin, no. 8246, January 22, p. 21.

1998c, Plutonic shareholders approve merger with Homestake - Gold: Metals Bulletin, no. 8274, May 4, p. 10.

Metal Bulletin Monthly, 1998, More BHP iron ore on the way: Metal Bulletin

Mine Development Business Leads, 1997, Alcan on track with bauxite mine: Mine - 1998, Australia still glitters—For now: Metal Bulletin Monthly, no. 330,

Development Business Leads, no. 1, April, p. 3. June, p. 61.

Minerals Gazette, 1996a, The monster to get bigger: Minerals Gazette, v. 1, no. 91, August, p. 7.

1996b, Uranium coming in from the cold: Minerals Gazette, v. 1, no. 86, March, p. 8.

Mines and Energy South Australia, 1997, South Australia - The jewel in the crown: Eastwood, South Australia, Australia, Mines and Energy South Australia, 4 p.

Mining Journal, 1997a, Aberfoyle approval: Mining Journal, v. 329, no. 8439, July 25, p. 66.

1997b, Cannington ramps up: Mining Journal, v. 329, no. 8450, October, 10, p. 301.

1997c, Election over land reform?: Mining Journal, v. 329, no. 8459, December 12, p. 481.

1997d, ...government support for SASE: Mining Journal, v. 329, no. 8459, December 12, p. 483.

1997e, Legislative change to help Kembla: Mining Journal, v. 328, no. 8432, June 6, p. 445.



## HATCH

### References Cited:

- 1997f, Market news: Mining Journal, v. 329, no. 8445, September 5, p. 203.
- 1997g, Mt. Lyell study: Mining Journal, v. 329, no. 8441, August 8, p. 119.
- 1997h, Oaky Creek expansion: Mining Journal, v. 329, no. 8458, December Australia 5, p. 461-462.
- 1997i, Olympic Dam extension: Mining Journal, v. 329, no. 8459, December 12, p. 487.
- 1997j, Production—Alcoa's bauxite compensation: Mining Journal, v. 328, no. 8435, June 27, p. 509.
- 1997k, Production—Australian copper boost: Mining Journal, v. 329, no. 8453, October 31, p. 365.
- 1997l, Production—BHP expansion: Mining Journal, v. 328, no. 8435, June 27, p. 509.
- 1997m, Queensland magnesium venture: Mining Journal, v. 328, no. 8412, January 17, 34.
- 1997n, Queensland mines commissioned: Mining Journal, v. 329, no. 8452, October 24, p. 337.
- 1997o, Record Australia gold output: Mining Journal, v. 328, no. 8417, February 21, p. 150.
- 1997p, Western Australia's gold miners struggle: Mining Journal, v. 329, no. 8455, November 14, p. 402.
- 1997q, Western Australia softens gold royalty: Mining Journal, v. 329, no. 8440, August 1, p. 82.
- 1998a, Alumina and bauxite: Supplement to Mining Journal, v. 330, no. 8483, June 5, p. 11.
- 1998b, Australia: Supplement to Mining Journal, v. 330, no. 8481, May 22, p. 4.
- 1998c, Australian coal verdict: Mining Journal, v. 330, no. 8476, April 17, p. 297-298.
- 1998d, Iron ore Australia's Asian hopes: Mining Journal, v. 330, no. 8477, April 24, p. 322.
- Pasminco Ltd., 1997, Pasminco welcomes issuing of Century leases: Pasminco Ltd. press release, September 19, 1 p.
- Petroleum Gazette, 1998, The quarter at a glance - Native title deal: Petroleum Gazette, v. 33, no. 1, first quarter, p. 42.
- Resource Information Unit, 1998, Register of Australian Mining 1998-99: Resource Information Unit, 652 p.
- Stewart, N., 1998, Asia and Australia—Annual review supplement: Supplement to Mining Journal, v. 331, no. 8489, July 17, p. 5-15.



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**HATCH**

**References Cited:**

UIC Newsletter, 1997a, Australia announces greenhouse measures: Uranium Information Center Newsletter, no. 6, November-December, p. 5.

1997b, Foreign investment policy change for uranium: Uranium Information Center Newsletter, no. 1, January-February, p. 4.

van Os, J., 1997, Australia's new copper mine: Metal Bulletin Monthly, no. 320, August, p. 31-33.

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