Mt. Cripps Karst Area
Implications of Karst for Proposed Limestone Quarry Sites

Report to
Western Metals Resources Ltd.

by

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Summary

- This report is a **preliminary assessment of four proposed sites** for a limestone quarry near the Hellyer Mine.
- The main area of limestone, which includes proposed areas A, B and C, is the Mount Cripps Karst Area. **This is a major significant karst area** that has suffered little disturbance and has been classed as "high grade wilderness". As such it warrants preservation in its current state. Any quarry site within it would compromise that integrity.
- **Alternative sources** of limestone should be considered. These could include the purchase of hydrated lime from an existing quarry such as those at Railton or Mole Creek; or exploration of other limestone areas in the region which have lower karst significance (see Appendix).
- **Sites A and B** lie within the main part of the Mt. Cripps Karst Area and contain many documented caves and other karst features. **They should not be quarried.**
- **Site C** at the northeastern end of the Mt. Cripps Karst is less well documented but appears to have some specific karst sites of significance. The main problem with this site is that it is at the upper end of the karst area, so any pollution of underground or surface streams could spread down through the whole karst area. **This site should only be considered as a last resort** and more work would be needed to fully assess the karst significance and problems.
- **Site D** is on the west bank of a large dam, Lake Macintosh. As such it is now partly flooded and isolated from the rest of the Mt. Cripps Karst and so **can be considered of less karst significance** and any pollution problems would be restricted to the local area, or to the dam itself – where cleanups would be much easier than in underground streams. **However, a more detailed study is needed in this area.** Note that this site could have other problems that are unrelated to the karst.
- Regardless of which site, if any, is chosen, **there are a number of potential problems that can be expected with any limestone quarry.** These include both threats to the karst values and hazards for the quarry operation that must be allowed for in the planning. These problems include:
  - the direct physical destruction of karst features;
  - slope and soil instability.
  - pollution of caves and underground streams by turbid runoff or chemical spills;
  - modifications to the surface and underground drainage.
  - opening of the forest canopy and introduction of weeds;
  - subsidence problems within the quarry and on the access roads;

Introduction

Limestone is needed for the control of acidity in mine tailings associated with the Hellyer Mine, operated by Western Metals Resources, in north-west Tasmania. Three potential quarry areas were selected within the Mount Cripps Karst Area by the company and I was asked to document the cave and karst features of the area and their relevance to each of the proposed areas. A fourth Area, on the west bank of Lake Macintosh, had already been rejected for reasons of visibility, but should be reconsidered as it would have less impact on karst systems than the other three areas.

The stated requirements are for two million tonnes of limestone taken over an operating period of about ten years. It is estimated that the quarry would occupy an area of about 200m square. The site must be within reasonable distance of the mine.

This report is a preliminary assessment of the proposed quarry areas, based on an assessment of published information, unpublished data collected by the Savage River Caving Club (SRCC) and a brief field inspection. The objective was to eliminate the least-suitable sites quickly and indicate the potential problems and further work needed to assess the remaining sites.

Note that I deal here only with karst values and karst problems. The sites will also need to satisfy other criteria - e.g. all appear to be within a declared wilderness area, and the southern sites could contribute sediment and pollution to Lake Macintosh.

Karst is a general term for all the special landforms and processes associated with limestone areas. Karst terms used here are listed in a glossary at the end of the report.

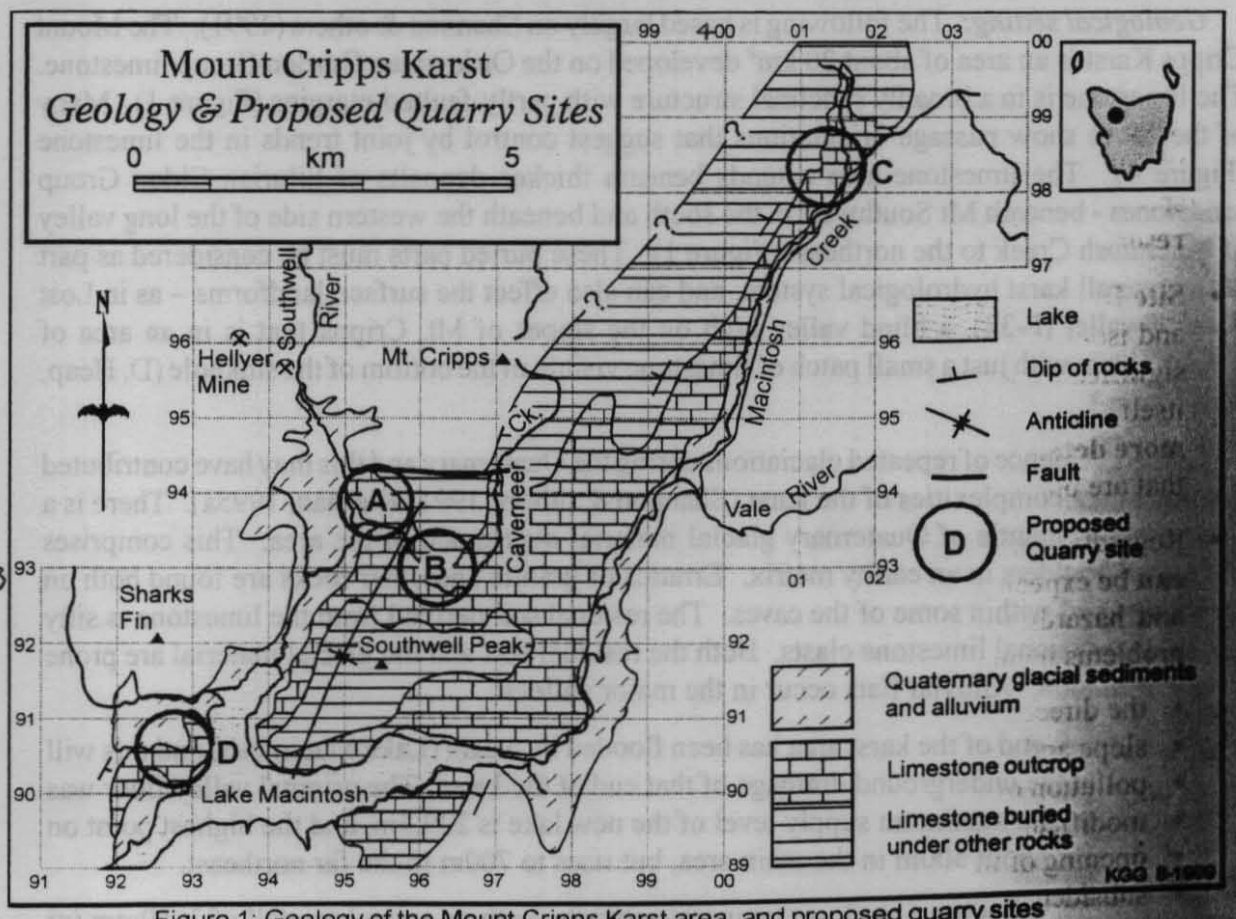

Figure 1: Geology of the Mount Cripps Karst area and proposed quarry sites

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The Mt. Cripps Karst

Existing information.

The main (southern) part of the area has been systematically explored and documented by members of the Savage River Caving Club (SRCC) over the past 11 years. This fieldwork and documentation was done in cooperation with the land manager - at that time North Forests (Warner, 1995). The principal published reports from the SRCC are by Shannon & others (1991) and Grey & Heap (1996); there is also much information in less-accessible club newsletters and files. Additional information has been gathered by other caving clubs and visiting experts - for example the cave faunas (summarised in Clarke, 1997). Summary reviews of the area and its significance appear in the Alas of Tasmanian Karst (Kiernan, 1995a), and the significance of the polygonal karst in the Tasmanian context is assessed by Kiernan (1995b). The extent of the limestone is shown on the 1:25,000 geological maps (Komyshan, 1986; Vicary & Pemberton, 1988). These maps have some minor errors in the boundary of the limestone which have been corrected in Figure 1.

The north-eastern part of the area, along Macintosh Creek, has had little cave exploration, and consequently little was known about its karst character. Likewise Area D, on the west side iof Lake Macintosh, has had only a couple of brief visits by the SRCC.

Note that 'Southwell Peak' and 'Caverneer Creek' (shown on Figures 1 & 2) are new names registered by the Savage River Caving Club.

The karst

Geological setting: The following is based largely on Shannon & others (1991). The Mount Cripps Karst is an area of about 20 km^2 developed on the Ordovician Gordon Group limestone. The limestone is in a broadly synclinal structure with partly-faulted margins (Figure 1). Many of the caves show passage orientations that suggest control by joint trends in the limestone (Figure 4). The limestone also extends beneath thicker deposits of Silurian Eldon Group sandstones - beneath Mt Southwell in the south and beneath the western side of the long valley of Macintosh Creek to the northeast (Figure 1). These buried parts must be considered as part of the overall karst hydrological system, and can also effect the surface landforms – as in Lost Creek Swallet (F-32), a blind valley high on the slopes of Mt. Cripps that is in an area of conglomerate with just a small patch of limestone visible in the bottom of the sinkhole (D. Heap, pers comm.).

There is evidence of repeated glaciations during the Quaternary and this may have contributed to some of the complexities of the karst (Shannon & others, 1991; Kiernan, 1995a). There is a discontinuous mantle of Quaternary glacial material over much of the area. This comprises gravel and boulders in an earthy matrix. Erratics of granite and other rocks are found both on the surface and within some of the caves. The residual soil derived from the limestone is silty clay with occasional limestone clasts. Both the residual soil and the glacial material are prone to severe erosion. Alluvial flats occur in the major valleys.

The southern end of the karst area has been flooded by a dam (Lake Macintosh) and this will have modified the underground drainage of that end of the karst. The original valley floor was at about 210m; the maximum supply level of the new lake is 229.5m, and the highest point on the limestone is about 500m in the main area, but rises to 700m in the far northeast.

Climate: The area has a cool wet temperate climate, with an annual rainfall of 2050mm (at the Hellyer mine).

Vegetation: The limestone is mantled by old growth rainforest with eucalypt emergents. The understory is relatively open for a Tasmanian rainforest. This is the only large karst area in east Australia which still has its natural forest cover intact over the whole area (Shannon & others, 1991). The complexity of the ground surface with numerous hollows, stream sinks and shaded cave entrances provides a wide range of micro-habitats within a small area (Grey & Heap, 1996).

The karst can be described in general terms as an *impounded karst* grading from *fluviokarst** (where it has retained some surface drainage) to true *holokarst* in which the drainage is entirely underground. It is a *deep karst* with the limestone and water flow extending well below the level of the main valleys - and below the present artificial lake. The visible part is an open karst, but there will be *capped karst* effects beneath the areas of Silurian sandstones and Tertiary basalt. The water input is mixed *autogenic* (local) and *allogenic* (external, from the streams bordering the area). Although glacial material is present and has entered some caves, it is uncertain at this stage whether the area should be regarded as a *glacio-karst* (formed by a combination of glacial and karst processes) or as a glaciated karst (prior karst, modified by glacial action).

Surface karst: Chains of dolines (sinkholes) follow many of the smaller valley axes (and the smaller 'streams' shown on the topographic maps are largely imaginary), but stream-sinks that engulf large permanent creeks are rare. One major exception is a major stream sink and associated dry valley found in the northeast (Area C) during this study. The most interesting form of surface karst is the area of polygonal karst in the southern part of the karst area

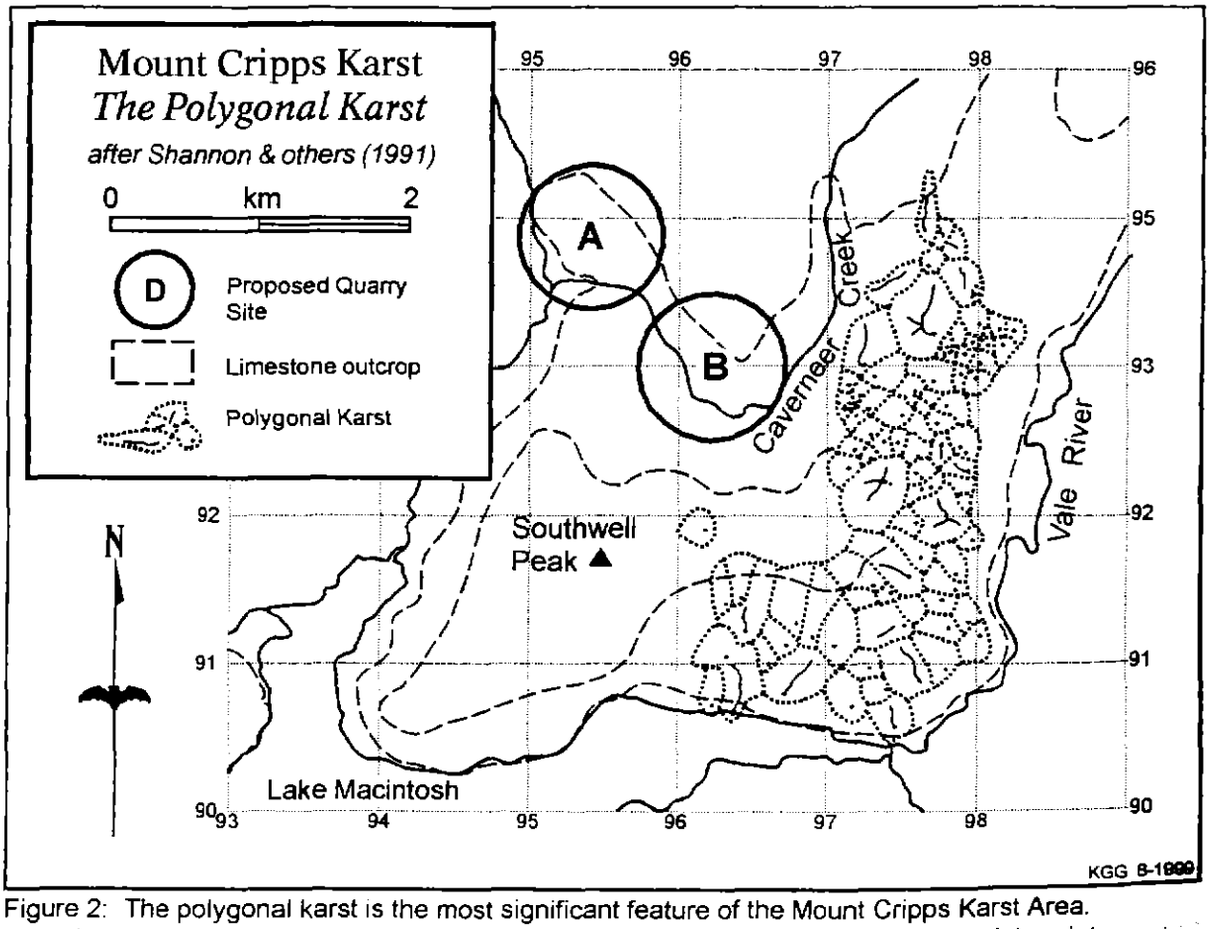

Figure 2: The polygonal karst is the most significant feature of the Mount Cripps Karst Area. Dotted lines are ridges bounding the dolines. Solid lines are streams and dots are sink-points.

* Karst terms are defined in the glossary

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(Figure 2). This is discussed in the following paragraph. Small springs are common and there are several large springs along the valley sides of the Vale and Southwell Rivers (Figure 5). Springs at the southern end of the area have probably been submerged beneath the artificial lake. Small scale solutional sculpturing (rundkarren) is common on the limestone outcrops. The rundkarren are rounded subsoil forms that suggest exposure by soil erosion - although it has been suggested that some of these may have formed under a thick moss or lichen cover (Shannon & others, 1991).

Polygonal karst is a term applied to a karst landform in which the whole surface is composed of sinkholes separated by a polygonal pattern of residual ridges (Figure 2). It has the appearance of the inside of an egg carton. It is a landform that is usually best developed in the humid tropics, but in Tasmania there are four areas where it occurs. Kiernan (1995b) discusses and compares these areas, noting that each has its own special character and that the Mt Cripps polygonal karst area is by far the largest and is the only site that remains wholly intact.

The Caves currently number in excess of 200 with exploration continuing. They are mostly small, but their distribution is unusually dense (Figure 3), and some individuals have up to 500m of passageway and reach depths of 80m. The general character is a set of interconnected joint and bedding-plane controlled fissures with occasional stream passages and larger breakdown chambers (Figure 4). Some are very well decorated, and some have unusual clastic speleothems. The levels rise and fall in an irregular fashion and vertical drops of up to 25m occur. Small streams enter many cave entrances, or are encountered in the lower levels. Most of the caves are the result of autogenic input through the epikarst, with the cave streams being fed locally from

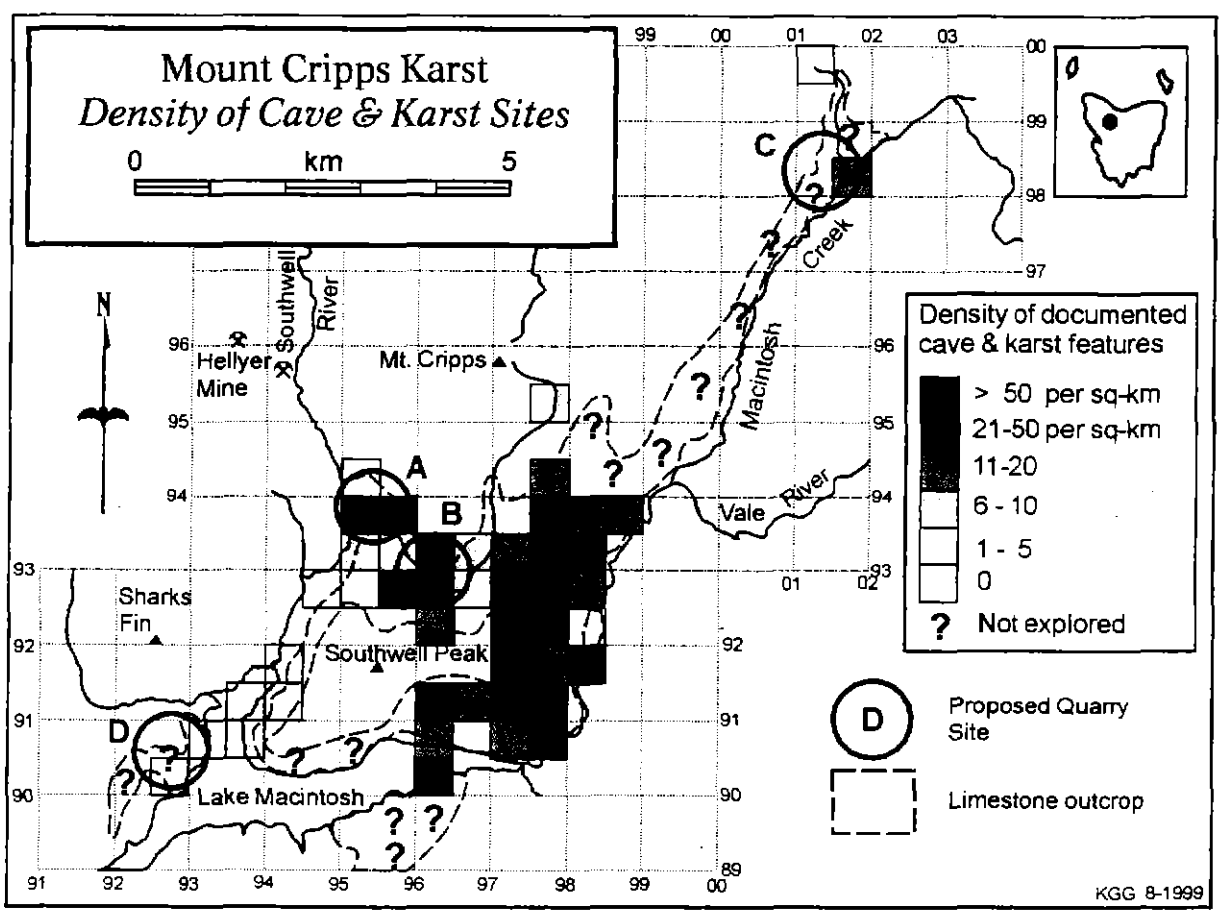

Figure 3: Density of documented caves and other karst features in the Mount Cripps Karst Area. Based on information provided by the Savage River Caving Club, and subject to the limits of current exploration (1999). Note that much of the Macintosh Creek area has not been explored.

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the surface. These underground streams tend to run only short distances before they sump or become impassible to humans. The character of the main drainage at depth is thus uncertain. On general principles one would expect a major set of deep conduits carrying water in a general southwesterly direction (as shown in Figure 5), but so far cave exploration has failed to find a connection down into this postulated master system. Shannon & others (1991) suggest that some caves may have formed from meltwater from past glaciers. Many of the caves appear to be older systems, dating to an earlier hydrological regime, that have been intersected by the present karst surface as it cut down into the limestone.

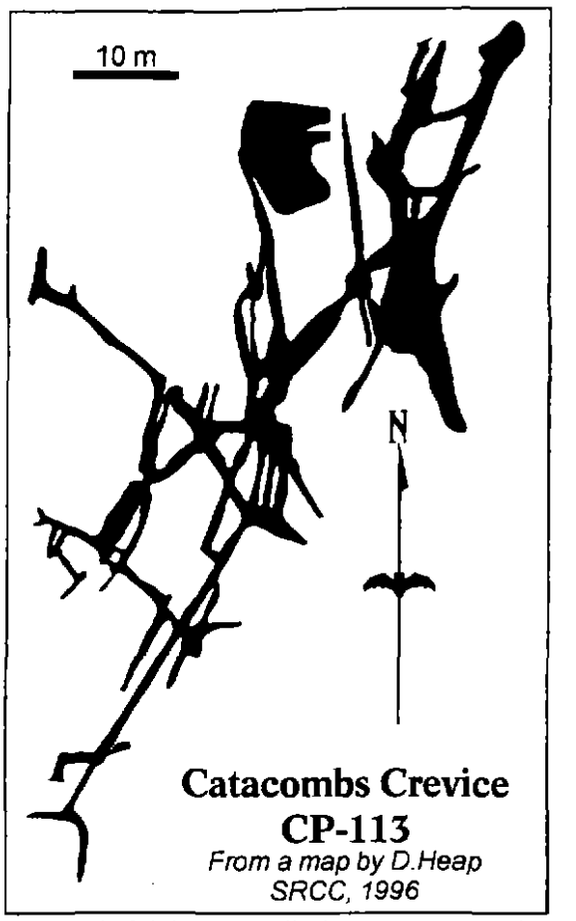

Figure 4: A joint-controlled maze cave in the southern part of Area B.

The cave sediments are mostly fine-grained muds and clays with a local gravel component; but locally there are sandy sediments which are probably derived from the overlying sandstone unit. In some caves the sediments are interbedded with speleothem layers, and contain embedded charcoal. Shannon & others (1991) indicated a potential value in the paleoenvironmental record contained in the cave sediments. This potential includes a possible record of multiple glaciations. Shannon & others (1991) also refer to the potential of the largely unstudied cave biology, mineralogy and bone fossils. Preliminary studies have been done on the biology, but the other areas still await research.

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Karst Hydrology

The karst hydrology is not well known. Heap (1999) lists known springs and major stream sinks. The small underground streams seen in the known caves appear to be mainly local effects of surface infiltration and they disappear into impenetrable holes before reaching the deep and presumably better organised drainage channels. The limestone forms a locally-faulted synclinal structure with the deepest parts extending well below the current valleys and beneath the level of the lake. Thus there is potential for an underground drainage that could cross the divide between the major surface valleys of Macintosh Creek - Vale River in the east and the Southwell River - Caverneer Creek in the west (Figure 5).

There were early reports of large outflow caves along the Macintosh and Vale Rivers, but these have now been flooded by the dam. A number of significant springs have been recorded in the southern area along the banks of the Vale and Southwell Rivers. A major stream sink and associated dry valley was found in the far northeast (Area C) during this study.

More work is needed on the hydrology. In particular additional exploration is needed along Macintosh Creek to attempt to locate inflow and outflow points in the northeast of the area. This may be difficult as preliminary exploration reported thick horizontal scrub in this area. This is a necessary precursor to dye tracing of underground flows which is needed to indicate the flow paths. However, these tracing experiments will be hampered by firstly the presence of the dam

which has probably submerged the main outflow points, and secondly the current lack of human access to the (postulated) main conduit caves at depth.

Pending further studies we must fall back onto general principles. The likely drainage would involve both local (autogenic) inputs via the many dolines and cave entrances within the area, and external (allogenic) inputs along the sides of the major streams at the margin of the area (Macintosh Creek, Vale River, and Southwell River). Known outputs are springs along the margins of the lower parts of the Vale and Southwell Rivers and into Caverneer Creek (Figure 5, information from SRCC & Heap, 1999) - there may be others that have not yet been found. There are also early reports by bushwalkers of major outflows in the valley now submerged by the lake - these would probably have been the main outflow points and are now inaccessible for testing.

Some of the local autogenic water input is rising again in local springs (e.g. Gurgle Spring, in Area A) and this shallow flow may also be feeding some of the springs along the margins of the area (e.g. those along the Vale River, Figure 5). But much of the water disappears down to lower impenetrable levels and there is probably a deep integrated system that was collecting both the allogenic and autogenic inputs and transmitting them southwards to the outflow points that are now beneath the dam. This hypothetical flow is shown in Figure 5). The southern end of this flow system will have been modified by the raised water levels of the dam.

The allogenic external inputs will be entering from the major surface streams, either directly into the limestone at the edges of the valleys, or via the porous alluvial floors. This water will move down-dip into the deeper parts of the karst system to join the postulated main regional conduits. These channels will probably be flooded epiphreatic systems.

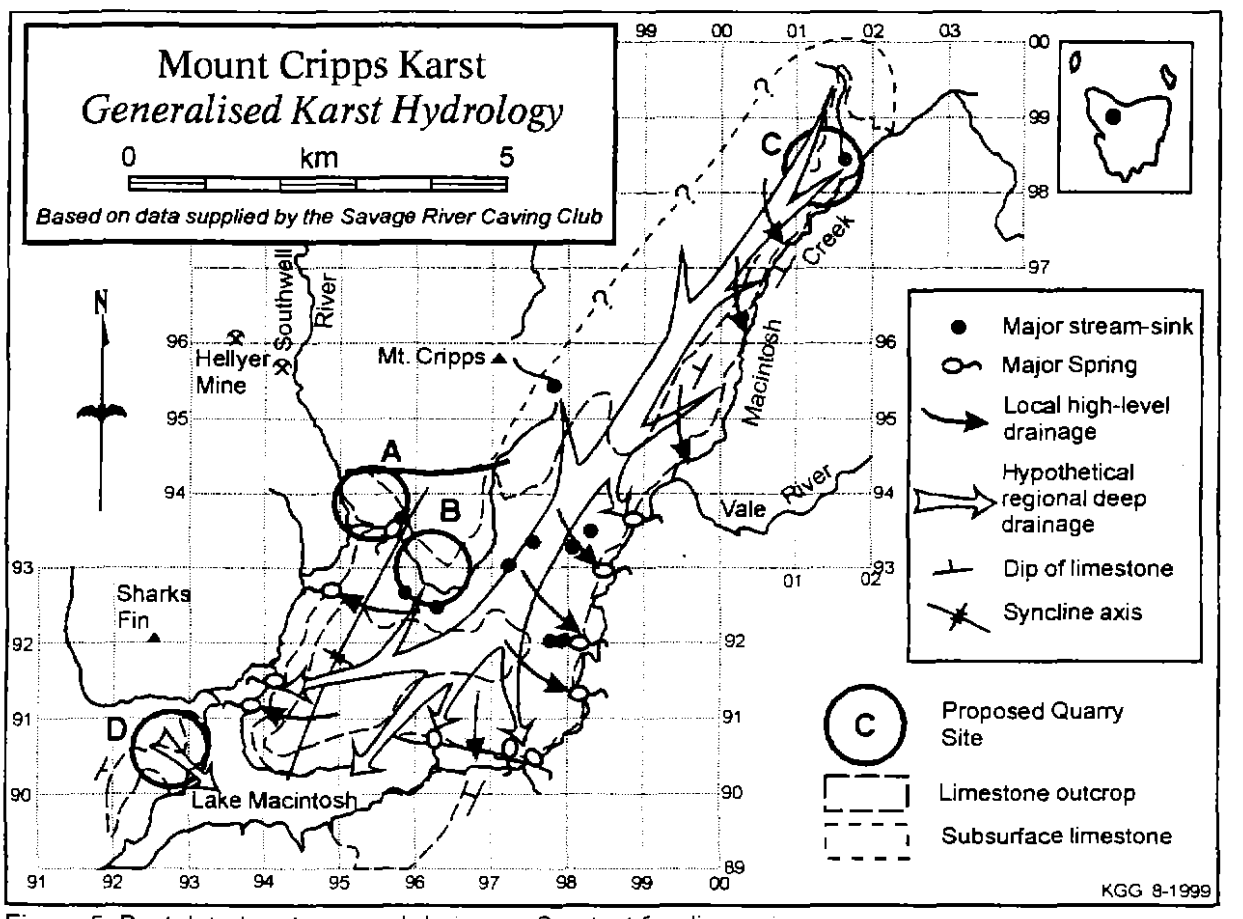

Figure 5: Postulated underground drainage. See text for discussion.

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Cave Faunas

Cave ecosystems are unusual and fragile systems. Many have been destroyed or damaged by deliberate human actions, or by a lack of understanding on the part of land managers. Even minor changes to water levels, humidity or substrate (e.g. by siltation) can cause major population crashes or changes and recovery can be very slow. Thus we must do our best to manage those karst areas that still remain in an undisturbed state. The Mount Cripps Karst is one such area where the cave ecosystems are still well preserved and have escaped the introduction of foreign species. It could provide a base-line reference for other karst areas in Tasmania.

Cave biologists have only briefly studied some of the caves at Mt. Cripps. A preliminary list of findings is given in Grey & Heap (1996), and the more significant species are mentioned by Clarke (1997). Initial studies from approximately one-fifth of the known caves in the Mt. Cripps karst indicates the presence of rich and diverse cave communities, composed of numerous aquatic and terrestrial species.

The Mt. Cripps karst area has already yielded a large number of endemic species, many of which are cave obligates: stygobites and troglobites (see Glossary for explanation of terms). These obligates include the recent discovery of several new undescribed species, such as the blind crangonyctoid cave amphipod: *near Giniphargus*, the cave harvestman: *Hickmanoxyomma sp. nov.* and the zolini cave beetle: *Pterocyrtus sp. nov.*

According to tables in Clarke (1997) two caves at Mt Cripps from which particularly rich cave faunas were collected are:

CP-6 APPM Cave : 11 terrestrial species; including 4 troglobitic terrestrial obligates and one possible troglobite. This cave lies within proposed quarry Area A.

CP-37 Philrod Cave: 28 species (5 aquatic & 17 terrestrial); including 3 stygobitic aquatic obligates, 4 troglobitic terrestrial obligates, 1 possible troglobite and 2 that are of uncertain status (troglophile or troglobite).

Bone material has been seen in several caves (Grey & Heap, 1996), but has not yet been studied in detail. Wombat bones have been found in several caves. This species does not live in rainforest which suggests a grassland vegetation at some time in the past. Thus the bone deposits and associated sediments could be useful in palaeoclimatic reconstructions.

Archaeology and Aboriginal heritage

Aboriginal usage of the caves has yet to be confirmed. Several cave sites found would have provided ideal shelter locations for aboriginals but no visible signs exist apart from some indications of fire (charcoal). The area was not always covered by rainforest and an aboriginal occupation site is known 5km to the south, now under Lake Macintosh. No excavations or other studies have been made in the caves.

Current status of the Mt. Cripps Karst

The karst and the surface vegetation is currently very well preserved. Only three types of disturbance have been recognised.

- The short section of forestry road into the limestone area north of Caverneers Creek. This has opened the canopy and introduced weeds, but it is of minor extent and the road has now been closed and is regrowing. Probably more significant is the rest of the forestry road, outside the limestone boundary - this is continuing to act as a corridor for weed introduction to the edge of the limestone.

- The flooding of the southern end of the karst by the hydro dam, Lake Macintosh. This has doubtless flooded some caves, and more importantly will have effected the underground drainage system in that area. This will hamper any efforts at unravelling the regional karst drainage.
- A bushfire in 1995 spread into the southern area and damaged the vegetation on the southern end of the polygonal karst (Grey & Heap, 1996). Fortunately most of the burn was in the areas of Silurian sandstone that caps the limestone around Southwell Peak. Recovery of the vegetation is being monitored.

Significance of The Mount Cripps Karst

This section discusses the significance of the karst area as a whole, and of the specific areas proposed as quarry sites. The likely impact of quarrying on the karst, and the karst hazards for the quarry site, are discussed later.

The Mt. Cripps Karst Region, taken as a whole, is significant for several reasons:

- It is a relatively extensive (>20 km^2) karst area that is still well preserved with minimum damage. Such well-preserved areas are becoming rare and as such deserve preservation for that reason alone.
- This is the only sizable karst area in east Australia which still has its natural forest cover intact over the whole area. This implies that the cave ecosystems should also still be in good condition.
- It is highly karstified and contains a high density of caves (211 documented to date in the southern part)
- It contains a variety of unusual karst features - in particular the well-developed polygonal karst, the glacial materials, and clastic speleothems.
- The Mt Cripps polygonal karst area is by far the largest of the four known examples in Tasmania and is the only site that remains wholly intact.
- It has its own particular cave fauna. Initial studies from caves in the Mt. Cripps karst indicate the presence of rich and diverse cave communities, composed of numerous aquatic and terrestrial species.
- It has been repeatedly glaciated and that may have contributed to some of the complexities of its karst morphology.

It has become obvious over recent years that to manage any karst area one must manage the whole area - in particular the whole hydrological system (Kiernan, 1988, 1995a & b). It is not enough to manage just individual caves or features. Thus a quarry in any part of the Mount Cripps Karst Area will have some impact on the area as a whole.

Significance of the proposed quarry sites

In detail, the areas proposed for quarrying all have some properties or specific sites of karst significance.

Areas A and B have been well explored by the SRCC but Area C is less well documented - essentially the only information on it is that gathered during this study. However, we can probably extrapolate from the better known areas to the south. Area D is also poorly documented but the SRCC have had a couple of trips to the area. It was not visited during this

study as it had already been removed from the list of sites - however it should be reconsidered as it an area in which any damage or pollution could be contained and isolated from the remainder of the karst.

Area A (North of Caverneer Creek)

The area contains many known caves and other karst features including several well-decorated caves. Some sites of specific significance include:

- **Cut Line Swallet** (CP-1) is a large blind valley with surface flow entering a small cave.
- **My D-Cline** (CP-2) is significant for its branching phreatic tube system - unusual for the area.
- **Choir Room** (CP-3) has documented mud stalactites - though these may prove to be common in the area.
- **APPM Cave** (CP-6) has a documented rich cave fauna (see above) - but further work may show that most species are present in other caves in the area. A long straw formation in this cave features as the frontispiece of the book "Beyond the Light" (Grey & Heap, 1996).
- **The Quasitomo - Gurgle Spring complex** (CP-29, 30 and F-3) provides an excellent example of karst hydrology. A surface stream runs through a relatively young cave which it has dissolved along a set of joints, re-emerges and sinks again into another cave and finally emerges at Gurgle Spring on the side of Caverneer Creek. The cave fauna includes glow worms.

Area B (Straddles Caverneer Creek)

This area is similar to the adjoining area A. It contains the following significant caves and sites.

- **O'Leary's Sink** (CP-52) is a karst window: Water emerges from one side of the deep doline and runs into a cave entrance on the other. The water is thought to come from Pool Sink, 200m away.
- **Optical Ole** (CP-101) has easy access from the road combined with good formations and a lake.
- **The Colosseum** is a large collapse doline with several caves - including **Xerxes Cave** (CP-110) which is particularly well-decorated and is reported to have a significant fauna.
- **Catacombs Crevice** (CP-113) is a complex maze system which is one of the larger caves in the area with 380m of passage (Figure 4). It is also well-decorated and is reported to have a significant fauna.
- **Gum Cave** (CP-120) has large decorations, including calcified tree roots and some large breakdown blocks.
- **Coccyx Cave** (CP-121) contains a calcified wombat skeleton - wombat remains have been found in several caves and indicate a different vegetation in the past. Dating of this bone material could provide paleoclimatic information.
- **Scalloping Pot** (CP-122) has solutional structures (scallops) that indicate the direction of a prior cave stream.
- **Epicin Cave** (CP-145) forms a major stream sink that is not far below the

sandstone/limestone contact - so the water input is mainly allogenic (derived from outside the limestone).

- The feature known as **Hollow Hill** is a limestone knob that contains many small caves and shafts.

Area C (Northeast Macintosh Creek)

This area is much less well documented and so I spent some time checking it myself. I inspected an area centred on the limestone knob at 014983. The knob and the slope and small valley to the north had good outcrop and well-developed rundkarren but no caves or dolines were found there. Descending the steep slope to Macintosh Creek I passed three small cave entrances and one large one. The three small entrances all connected to steep-dipping narrow shafts which I did not enter. The larger entrance was checked, but led to only a small cave. This single traverse indicates that there are caves present in the area but their extent or significance is still uncertain. In the valley there were some significant features. A tributary valley about two kilometres long enters the valley of Macintosh Creek at 015981. About 400m upstream from this junction there is a major stream sink (at about 016984) that take the entire flow of the creek coming down the valley. The water sinks into a series of small holes against the east wall of the valley. Below that the stream channel terminates against a 4m high earth bank. Between here and the Macintosh Creek junction we have a "dry valley" that lacks any surface stream channel. Occasional scour hollows with stagnant pools indicate that major floods overload the stream-sink and continue down the dry valley to the junction.

Although there would seem to be some cave potential the main karst significance of this area currently lies in the dry valley and major stream sink described above. However, more exploration will be needed to document the full extent of karst features in this area.

Area D (West of Lake Macintosh)

This area, on the west bank of Lake Macintosh, had already been eliminated when I commenced the field work so it was not visited. The SRCC have visited the area briefly and found only a few small caves and sinkholes. An inspection of the air photos suggests that there might be some larger dolines or possibly even a small area of polygonal karst in the southern half of the area (south and west of 925905). Area D is now separated by the artificial lake from the rest of the karst area. However that is a recent event and the caves, hydrology and cave fauna would be similar to the main area. The hydrology has suffered the main change as a consequence of flooding of the lower sections of the cave systems.

Possible Alternative Area (West side of Southwell Peak)

This was not an area selected by the company - but was suggested by SRCC members as a site with few known caves. Being close to the lake, any pollution problems from a quarry would most likely move south and into the lake - avoiding problems for the karst, but possibly causing other problems for users of the lake. I inspected part of the area and found one major spring but no caves. However, there was little limestone to be seen and I suspect that, contrary to the geological map, the overlying sandstone unit extends nearly to the foot of the slope. Thus it would probably not be useful as a limestone quarry site.

Management Considerations for Karst

Karst is special environment in that much of the activity within it occurs beneath the surface – out of sight, and unfortunately often out of mind of the land managers. A company operating a quarry in karst becomes the defacto manager for that karst. Managers of karst areas must be aware of the underground processes and environment. They must also realise that management must be of the whole karst area, and adjacent drainage areas that are feeding water into the karst. There is little point in preserving a cave entrance if a farm or quarry several miles away is dumping pollution into a sinkhole that connects underground to the back of the cave. The concept of "underground rivers" is very real in karst. Such open conduits can carry water and pollution rapidly over long distances and with little filtration.

Enclosed with this report is a copy of a booklet that give broad management guidelines for cave and karst protection (Watson & others, 1997). Kiernan (1988) presents a more detailed listing of problems that can occur in karst areas - with many Australian examples. The proceedings of a series of major symposia on the engineering problems of karst have been published by A.A.Balkema over the last 15 years (e.g. Beck & Stephenson, 1997). Clarke (1997) also lists potential karst problems in Tasmania.

The two volume *Atlas of Tasmanian Karst* prepared by Kiernan (1995) is an invaluable resource for anyone considering development within limestone areas in Tasmania. It contains both a comprehensive overview of the problems and special management requirements of karst and also a summary of the known karst areas of the state - indicating (as far as is possible using the existing knowledge) the general character, significance and likely management problems of each area. The Appendix to the present report provides copies of the atlas entries for the Mt. Cripps Karst (W-10), Area D (W-8) and also for other karst areas in the region that might be considered as alternative sources of limestone.

Managing the karst hydrology

Managing the karst hydrology is the key to managing any karst area. The importance of maintaining drainage patterns and water chemistry in as close to a natural condition as possible cannot be overstressed. The total catchment of the karst area must be managed as an integral unit (regardless of arbitrary property boundaries).

Karst hydrology can be complex and unpredictable. Underground streams can exist and can flow in directions unrelated to the surface topography. The direction of underground flow can also vary dramatically depending on the level of flow through the system - flood overflow routes can follow older, fossil passages in a quite different direction to that taken by the more recently formed low stage conduits. Flow can be fast, and the lack of filtering in the open conduits means that pollutants can travel long distances and at rapid rates. Thus an important first step in karst management is to gain an understanding of the underground plumbing.

This is done by first compiling detailed inventories of karst features (especially sinks and risings) followed by delineation of drainage maps by studying underground flows exposed in cave systems and by water tracing techniques. In areas such as Mt Cripps, where the main conduits are not accessible via the caves, there is little alternative to a series of water tracing tests. Continuing monitoring of the groundwater flows and quality is necessary.

Potential management problems in limestone quarries

Here I discuss not only the impact of quarrying on the karst, but also the karst hazards which exist for the quarry and associated roads and plant. For quarry sites in particular the following problems have been met elsewhere and must be considered in the present situation - regardless of the actual quarry site chosen.

- ***Turbid or polluted runoff*** from the site, and associated roads and work areas. Turbid water is a major problem in wet climates such as this. It can cause sediment buildup within nearby caves. This is detrimental to the cave fauna and can also clog constrictions in the underground plumbing - redirecting the water to other areas or routes and causing unexpected flooding. Flocculated clays can travel considerable distances in underground streams. Pollution can include oil and fuel or other chemicals (e.g. ANFO explosives). It can also be from faulty septic systems - possibly following damage by karst subsidence. Rubbish dumps can contribute a variety of pollutants. The experience at the Exit Cave Quarry (Lune River) in southeast Tasmania is a well-documented example: mud from the quarry there completely blocked some cave passages, and threatened the ecosystem of Exit Cave. At the same time petroleum and faecal pollution from the quarry work area appeared in another cave (Houshold & Spate, 1990; Houshold, 1992; Gillieson, 1996, p 290-296).
- ***Changed water movement patterns.*** A quarry will cause changes in the volume, location, and nature of water input into the underground karst system. This can effect both the local cave ecosystem and the regional drainage pattern. The effect can included both increases in flow in some places from new or redirected runoff, and decreases elsewhere following diversion or plugging of prior input points.
- ***Soil and slope instability.*** This is typically associated with the access roads as well as the actual quarry faces and adjoining cleared slopes. This instability can contribute to the turbid runoff problem, and also pose a hazard to workers and machinery on the site. Runoff directed into soils downslope of the site can saturate them and cause instability there also. One consequence of landslides is the sudden delivery of slugs of sediment to the local cave systems and karst plumbing.
- ***Sinkhole activation.*** This can be more than just a nuisance - requiring repairs to roads and other work surfaces. Water pressure in a settling pond can trigger a sinkhole beneath its floor - draining the pond and delivering a sudden slug of slurry or turbid water to the underground caves and conduits. Loading of surfaces with rubble or soil dumps can also cause collapse and subsidence. Artificial lowering of the water table by pumping in a quarry pit can remove hydrostatic support of previously flooded cave roofs and thus trigger sinkhole development in nearby areas.
- ***Introduction of exotic species***. Weeds are carried as seeds along roads by vehicles. Some weeds have already invaded along the forestry track that approaches the main karst area from the north (Grey & Heap, 1996). Effective control of such weeds can be very difficult.
- ***Cavity interference with blasting***. Unpredicted cavities in the limestone can cause unexpected blast effects, with the danger of fly rock, and of associated subsidence or collapse of unexpected areas. For example a few years ago a "routine" blast in another Tasmanian quarry resulted in an unexpected major collapse of several quarry benches and the effect spread beyond the quarry towards an adjoining railway line.
- ***Direct destruction or damage to karst features.*** Although this is the effect which has

caused the greatest outcry in the past, it can be minimised by making a detailed inventory of caves and other features before development commences. The site location can then be adjusted to avoid critical caves or it might be considered reasonable to sacrifice some less significant features. However, not all caves have identifiable connections to the surface and some may still be unexpectedly intersected by the quarry.

- ***Blast damage to caves.*** With modern blast methods structural damage to caves from blasting can be limited to a fairly close proximity to the blast (less than 100m), but beyond that distance resonance effects can sometimes shatter delicate and apparently robust speleothems in an unpredictable manner.

- ***Changes to air-flow within caves.*** The cave ecosystem is dependent on a steady state and maintenance of temperatures, humidity and levels of carbon dioxide in the air. Some cave fauna (e.g. glow worms) are dependent on air movement for their food supplies. Breaching of new cave entrances or plugging of old ones can cause changes in air flow that can alter any of the above-mentioned factors.. Thus as well as controlling water flow we need to control air flows.

Considerations when developing and managing a Limestone Quarry

Most of what follows would apply to any quarry site that might be selected in karst - but is written for Areas C or D in particular.

In the **exploration stage** one should try to minimise construction of access roads and vegetation disturbance in general. The first step, before any access roads are constructed, should the be documentation of cave and karst features in the proposed site and road access corridor and development of a drainage map. This will allow routing of the access roads so as to avoid the likelihood of turbid runoff into major sinkholes and cave entrances.

Roads should avoid steep slopes, and construction should attempt to minimise undercutting of slopes as this could cause instability of the soil or glacial sediments. Likewise one should try to avoid spilling of road-cut material downslope from the road as this can destroy large areas of vegetation and destabilise the slope. Land slips may result - directing mud into caves and threatening the road above. Runoff from roads should be planned carefully. On the one hand we need to avoid directing turbid or voluminous waters into existing sinkholes or caves. On the other hand the water must go somewhere - and ponding in dams or infiltration from drains is likely to trigger new sinkhole development. Some possible approaches are: The use of dispersion into areas of natural vegetation; use of filters or walls around sinks and cave entrances; use of local small settling ponds, with sealed beds; and use of sealed drains to prevent concentrated infiltration beneath them. Weed introduction along roadways is a difficult problem. The only real solution is regular and dedicated patrolling of roadsides and removal of all weeds seen. Keeping a set of local vehicles that do not leave the site, and preventing outside vehicles entering it may assist if this is feasible. The change-over point would have to be where outside trucks load the final product from the crusher plant- ideally this should be outside the karst area.

In the Quarry itself the main problem again is water & mud control. The quarry should be sited to avoid any major sinkholes or cave entrances identified in the inventory stage and should also be away from any identified underground drainage channels. For any holes encountered during quarrying th eonjective should be to try and maintain the pre-existing water and airflow character. Thus holes should be plugged if they were originally closed to the surface, or provided with a filter if there is evidence of a prior (clean) water connection to the surface.

Clearing of vegetation ahead of the advancing quarry face should be kept to as small an area as possible as the exposed soil will be a major source of mud and turbid water. Soil and overburden dumps should be in areas where runoff from them will not be a problem - perhaps off the edge of the karst area if that is feasible. The weight of these dumps could trigger subsidence so they must be monitored and moved if subsidence does occur. All runoff should be directed to settling ponds (with a quality seal to prevent leakage if minor subsidence occurs) or to broad flat areas of natural vegetation (if such exist) where the mud can be filtered or settle out before the water goes underground. Ponds should be regularly monitored for leakage.

Blasting is less of a problem with modern techniques such as the use of smaller charges and delay detonators to generate smaller individual shock waves rather than one large one.

Workshops, fuel tanks, the crushing plant etc. are potential sources of pollution by oil, fuel, other chemicals, rubbish and human waste. Ideally these places should be kept off site - outside the karst area. If that is not feasible then provision should be made to contain and remove any likely pollution and to regularly remove rubbish. Septic toilet tanks have a habit of cracking and leaking into the karst because of subsidence - a dry composting toilet would avoid this problem.

Final closure and rehabilitation of the quarry should attempt to restore the soil, vegetation, and most importantly, the underground drainage. Any major water input points encountered during quarrying should be rehabilitated so that they are functioning in approximately their original fashion. This might involve placing filter walls around them - as was done in the Exit Cave Quarry (Gillieson, 1996). All structures and rubbish should be removed and once revegetation is complete all access roads through the karst should be closed and revegetated.

If a long low quarry is used (e.g. to avoid visibility at Site D) some restoration could commence as the quarry moves laterally. This would minimise the size of soil and overburden dumps and their associated problems.

Karst impacts of the proposed quarry sites

The four proposed areas for quarries are shown on Figure 1 and their karst significance has been discussed above.

General comments on all the proposed areas

The potential management problems in limestone quarries discussed above apply to all the proposed quarry areas. Some people will argue that the relatively undisturbed nature of the Mt. Cripps Karst area as a whole is a sufficient reason for not having a quarry site anywhere within it. A quarry in any part of the Mt Cripps Karst is likely to have some impact on the karst water system, and thence on the stygofauna. Nearby caves and surface features will suffer additional impacts. Even with the best planning and forethought some accidents, such as petroleum spills, are likely. Thus areas A, B and C are unfavourable even before we look at them in detail.

Area A (North of Caverneer Creek)

In addition to the impact on the integrity of the Mount Cripps Karst as a whole, a quarry here would directly or indirectly damage a number of significant caves and karst features. Pollution could spread through underground channels to the areas further south. **This area should not be quarried**

Area B (Straddles Caverneer Creek)

This area has similar values and problems to that of the adjoining area A and the impact of quarrying would be even greater as it is more central within the karst. **This area should not be quarried.**

Area C (Northeast Macintosh Creek)

As for areas A and B, a quarry here would reduce the integrity of the Mt Cripps karst Area as a whole. This area is the highest part of the Mt Cripps Karst area, and so any pollution problems here could travel south into the main karst area. A brief field visit indicated that there are karst features present, but no major caves were found. The most significant karst feature seen was a major stream sink and associated dry valley. Further field work will be needed to map the location of any critical caves or other features. **Overall, this is not a good site for a quarry.**

If the company wishes to continue considering this site then **it will be necessary to do a further, more detailed, field study** of the karst features present before a final decision can be made. In particular a detailed hydrological study would be needed to ascertain the nature of the underground water flow. This last could prove difficult as likely outflow points downstream may be hard to access.

Area D (West of Lake Macintosh)

This area, on the west bank of Lake Macintosh, had already been eliminated when I commenced the study so it was not visited during the field work. The reason given for eliminating it was the possibility of visibility of the quarry from Cradle Mountain.

The SRCC have visited the area briefly and found only a few small caves and sinkholes. **From a purely karst viewpoint this would probably be the area with the least problems** as it is now separated from the remainder of the karst area by the lake - so any hydrological problems would be unlikely to extend beyond the local area. However, the effect of any

pollution on the lake would have to be considered. The is also a possibility of aboriginal occupation sites being present and an archaeological study may be required.

Concerning visibility. Figure 6 shows a pair of profiles drawn from the 1:100,000 contour map. Looking from Cradle Mountain the critical blocking hill is at 000882 and it seems that the ridge at the quarry Site D (924905) would be about 150m below the line of sight and therefore concealed from Cradle Mountain. From Barn Bluff the critical blocking feature is a south-sloping hillside at 980872. The ridge at 924905 would just be visible from Barn Bluff as would be much of the ground to the south of it. However, the limestone ridge in the northern part of Area D would probably be hidden behind the rising hillside at 980872. This northern ridge curves around in front of a narrow valley and creek and so could provide a screen from people on the lake for a long, low quarry set on the north side of the creek (i.e. at 928905).

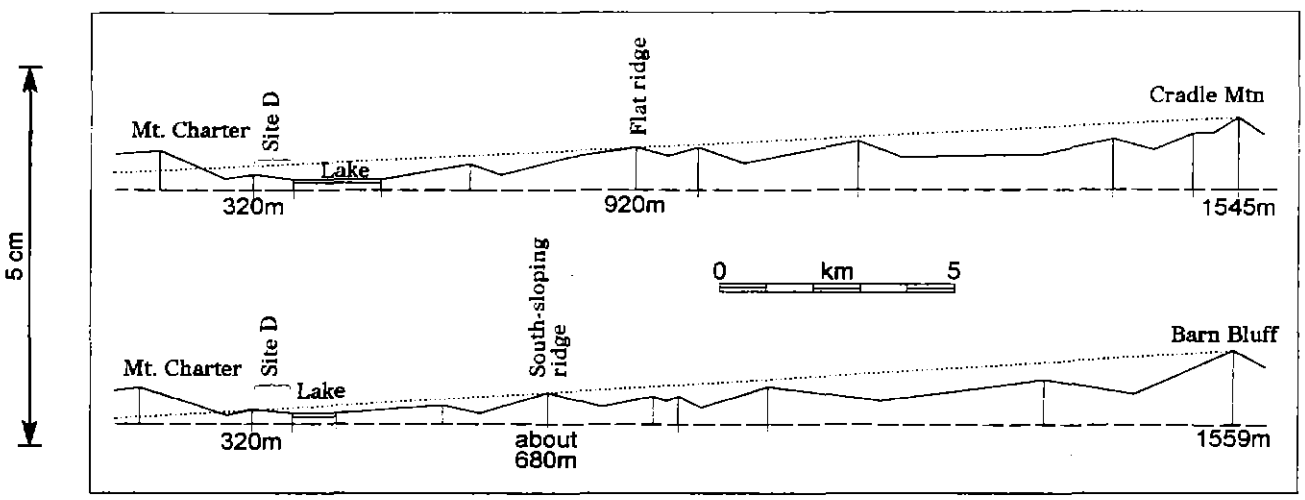


Figure 6: Estimated visibility lines. Based on contours on the Sophia 1:100,000 topographic sheet.

Extrapolation from the main area suggests that some significant features could be present - but the area is isolated by the lake from the rest of the area and a compromise could possibly be reached. **This area could be reconsidered if the other (non-karst) objections can be dealt with.** However, **if so, it will be necessary to do a more detailed ground study** to document any karst features that may be present - both at the quarry site, and along the access road from the northwest, and to determine the hydrology of the area. The company will also have to negotiate with the lake management and other land management bodies concerning impact on other values.

Alternative Area: West side of Southwell Peak

This is not an area selected by the company - but was suggested by SRCC members as a site with few known caves. I inspected part of it and found one major spring but no caves. However, there was little limestone to be seen and I suspect that the overlying sandstone unit extends nearly to the foot of the slope. Thus it would probably not be a usable quarry site.

Regardless of its karst values, **this area would seem to have little potential for quarrying.**

Recommendations

- The company should consider **alternative sources** of limestone from existing quarries in environmentally less-sensitive areas. For example, the quarries at Mole Creek or Railton.
- The company should investigate **alternative sites** in other limestone areas of lower karst significance. See the site information in the Atlas of Tasmanian Karst (Appendix 1) for an indication of the apparent karst significance of nearby areas.
- Each of the three proposed quarry **areas A, B and C would violate the overall integrity of the Mount Cripps Karst Area**. These sites should therefore be avoided.
- **Areas A and B should not be quarried.** They have many significant documented caves and karst features.
- **Area C should only be quarried as a last resort**, and then only if a detailed study indicates that there are few specific site of value within it **and** that the quarry will not threaten the downstream continuation of the karst via silting or pollution of underground and surface waters (demonstrating this might prove difficult).
- **Area D should be reconsidered** as it is now isolated from the rest of the karst area by the lake - so any pollution problems will be restricted to the local area and the adjoining lake. **This is the area that would have the least impact on the karst.** However, a more detailed karst study should be made before the location and access to any quarry is planned.
- If Areas C or D are chosen for further investigation then **a more detailed study of the caves and karst and associated underground drainage in those areas must be made** (see next page). This will also apply to any new sites identified in other areas.
- **The company must accept the role of de-facto karst manager for any quarry site.** The existence of karst problems and values must be borne in mind throughout the life of the project. This includes the exploration stage, development, continuing operation, and final closure and rehabilitation of the site. Significant planning to avoid karst-related problems will be needed regardless of the location of the final quarry. This includes both avoidance of damage to the karst system, and avoidance of karst hazards to the quarry operation.

The Detailed Karst Study

When an area is selected for quarrying then a more detailed study of the local karst features and the karst drainage will be needed before the exact quarry site and its access road is decided on. This will enable the avoidance of specific problems within the site, or at least their minimisation and control.

Site exploration & documentation of karst features

The members of the Savage River Caving Club should be encouraged to explore any proposed quarry area(s) in detail and document any caves and other karst features that they may find. The company should make an effort to cooperate with the cavers - they are a source of invaluable expertise and underground man-power, and if dealt with openly they should be willing to cooperate in the study.

There is, of course, a risk that cave exploration or the subsequent hydrological experiments could indicate that there is an important cave or karst feature at or near the proposed site. However, it is better to discover this before too much money has been spent on development rather than later when the company is committed to a specific site. Moving the site or roadway a few hundred metres might be feasible in this sort of situation.

Hydrological study

The mapping of the underground drainage patterns involves two steps. First one must identify any stream sinks, cave streams, and springs in and adjacent to the proposed quarry site and its road access corridor. This could be done by the cavers under supervision of a karst geomorphologist. Having identified the main input and outflow sites one can move onto the second stage. Water tracing experiments and other methods would be used to try and identify the nature of the underground plumbing - in particular to determine the path that will be taken by turbid or polluted water leaving the site and its roads and its final destination. This would involve inserting a non-toxic dye (e.g. fluorescein or rhodamine WT) into any identified water entry points near the quarry and sampling the waters rising at the springs or within the caves at intervals over a period of several weeks.

Unfortunately, the presence of the artificial lake at the downflow end of the Mt Cripps Karst system means that some or most of the critical outflow points of the karst plumbing may now be inaccessible. This could defeat attempts at regional water tracing but more local problems may still be identifiable.

REFERENCES

BECK, B.F., & STEPHENSON, J.B. [eds] 1997: *The Engineering Geology and Hydrology of Karst Terranes.* A.A. Balkema, Rotterdam. 516 pp.

CLARKE, A., 1997: *Management prescriptions for Tasmania's cave fauna.* Report to the Tasmanian Regional Forest Agreement Environment and Heritage Technical Committee.

GREY, L., & HEAP, D., 1996: *Beyond the Light: the Caves and Karst of Mount Cripps.* Savage River Caving Club, Burnie. 118pp.

HOUSHOLD, I., & SPATE, A.P., 1990: The Ida Bay Karst Study. *Report to the World Heritage Planning Team, Department of Parks, Wildlife & Heritage, Tasmania.* 2 volumes.

HOUSHOLD, I., 1992: Geomorphology, water quality and cave sediments in the eastern passage of Exit Cave and its tributaries. *Unpublished report to Department of Parks, Wildlife & Heritage, Tasmania.* 18 pp.

GILLIESON, D.S., 1996: *Caves: Processes, Development, Management.* Blackwell, Oxford. 324 pp.

HEAP, D., 1999: Hydrology at Mount Cripps (Part 1). *Speleopod.* **27.**

KIERNAN, K., 1988: *The Management of Soluble Rock Landscapes.* Speleological Research Council, Sydney. 61 pp.

KIERNAN, K., 1995a: *An Atlas of Tasmanian Karst.* Tasmanian Forest Research Council, Inc. Research Report No 10. 2 volumes. [*this two volume report can be purchased for $80 from the Forest Practices Board, Hobart*]

KIERNAN, K., 1995b: Geoconservation in Karst Areas. *Proceedings of the 11th Australasian Conference on Cave and Karst Management.* Aust. Cave & Karst Management Association. pp 3-16.

KOMYSHAN, P., 1986: *Map 1. Geology of the Mt Charter - Hellyer area (1:25,000).* Geological Survey of Tasmania, Hobart.

SHANNON, H., DUTTON, B., HEAP, D., & SALT, F., 1991: The Mount Cripps Karst, northwestern Tasmania. *Helictite*, **28(1)**, 3-7.

VICARY, M.J., & PEMBERTON, J., 1988: *Map 7 - Geology of the Back Peak - Cradle Mountain Link Road area (1:25,000).* Geological Survey of Tasmania, Hobart.

WARNER, A., 1995: Mt Cripps Karst Management - Land management, thoughts and actions. *Proceedings of the 11th Australasian Conference on Cave and Karst Management.* Aust. Cave & Karst Management Association. pp 97-102.

WATSON, J., HAMILTON-SMITH, E., GILLIESON, D., & KIERNAN, K., [Eds] 1997: *Guidelines for Cave and Karst Protection.* International Union for Conservation of Nature and Natural Resources, Gland, Switzerland and Cambridge, UK., 63 pp. [*a copy of this booklet has been sent along with this report*]

Other way around? see p. 7

GLOSSARY
of karst terms

For further information on general karst and speleological terms see Jennings, J.N. (1985) *Karst Geomorphology*. Blackwell, Oxford. or Gillieson, D.S., (1996) *Caves: Processes, Development, Management*. Blackwell, Oxford.

Allogenic water input: Water entering the karst directly by rainfall (or snow). c.f. Autogenic.

Autogenic water input: Water entering the karst by runoff from adjoining non-limestone areas. Thus the water chemistry may have distinctive properties, and is usually unsaturated and therefore aggressive (qv). c.f. allogenic.

Blind Valley: A valley that is closed off at its downstream end, all its water sinking at or near that point.

Breakdown: In a cave; piles of rubble or blocks that have fallen from the walls or ceilings.

Capped karst: Karst that has an impermeable cover (in this case the Silurian sandstones) c.f. open karst.

Cave: As used by speleologists, this means an underground cavity, fissure, or tube large enough for penetration by humans. Speleologists exclude 'rock shelters' (q,v.) and most 'sea caves', by either stipulating that the cavity must penetrate further into the ground than the largest dimension of its opening, or by requiring that it should have a permanent dark zone. For the layman, the term 'cave' is commonly used to include rock shelters, and also to describe a single chamber within a cave system.

Clastic speleothems: Speleothems (q.v.) formed from clastic materials (typically mud and silt, but occasionally cemented sand or gravel).

Deep karst: A type of karst in which the limestone extends well below the regional base-level that determines the water table. Thus there is an extensive zone of deep phreatic water. c.f. perched karst where there is shallow impermeable rock beneath the limestone that effects the water flow.

Diffuse input: The situation where water enters the karst diffusely through a porous cover; e.g. soil, surficial sediments or porous rocks (e.g. sandstone). c.f. point input.

Doline: A closed depression formed by karst processes. **Collapse Dolines** form by collapse of the surface rocks into an underground cave. **Solutional dolines** form by direct solution at the surface. **Subsidence dolines** form by the downward movement of loose surface material such as soils into an underground cavity.

Dry Valley: A valley in karst terrain that no longer has a surface flow of water. The talweg may undulate with many closures, and there is no longer a distinct channel.

Efflux: Another word for a spring or rising (q.v.).

Epikarst: The uppermost part of the karst surface - comprising the soil and underlying zone of broken rock. It may form a significant surficial aquifer.

Fluviokarst: A type of karst in which surface streams and valleys still play a significant role. c.f. holo-karst.

Glacio-karst: A type of karst landform in which glacial and karst processes have worked hand-in-hand.

Impounded karst: A karst system that is constrained by surrounding insoluble rocks - limiting or directing its development.

Holo-karst: The most fully-developed karst system, in which no integrated surface drainage forms remain. c.f. fluviokarst where surface streams and valleys are still a significant part of the system.

Karren: Small-scale sculpturing forms developed on limestone surfaces - either exposed to the rain, or buried beneath the soil.

Karst: The general term for landforms such as caves, dolines (q.v.) and sculptured rock surfaces, which are formed mainly as a result of the solution of rocks, in particular limestones.

Length of a cave: When a cavers refer to the length of a cave, they generally mean the total passage length. This is invariably more that the distance from one end of the cave to the other (referred to as 'cave extent'), as the passages will wind, branch or even form complex mazes. Total passage length is a useful guide to the significant size of a cave, but ignores the visual significance of large chambers. This approach can confuse laymen (and the media) who may think of the length as referring only to the largest chamber, or the overall extent of the cave.

Open Karst: A karst area in which the limestone is exposed at the surface without any capping. c.f. capped karst.

Perched karst: A type of karst in which a bed of shallow impermeable rock beneath the limestone constrains the underground water flow. c.f. deep karst.

Phreatic: That part of a cave environment that lies below the watertable. Also refers to the processes that act within the phreatic zone.

Point input: The situation where water enters the karst at restricted points such as discrete stream slinks, cave entrances, or the bottom of sinkholes. c.f. diffuse input.

Polygonal karst: A type of (generally) humid tropical karst in which the land surface is composed entirely of intersecting dolines separated by narrow polygonal ridges.

Rundkarren: A type of karren (q.v.) which develops beneath a soil cove. Characterised by smoothly rounded grooves and ridges.

Rising: A fancy term for a spring.

Rock shelter: A cavity formed by overhanging rocks, typically at the base of a cliff. Rock shelters are often referred to as 'caves' by laymen and can be significant for archaeology, but cavers prefer to exclude them from the definition of a 'true' cave (q.v.) as they do not penetrate any distance into the rock, and generally have no dark zone.

Semi-blind valley: A blind valley (q.v.) in which a dry valley (q.v.) continues below the stream sink and is still occasionally used by flood waters.

Scallops: groups of shallow, sharp-edged, hollows on a limestone surface which result from solution by flowing water. The shape of the scallops can indicate the flow direction, and also give an idea as to its velocity.

Sink (Streamsink): A place where a surface water course disappears underground.

Sinkhole: Strictly, a hole or doline which acts as a streamsink. Unfortunately, the word has become debased by common misuse as a synonym for a doline (q.v.), especially a collapse doline. It is used here as a synonym for doline.

Speleogen: A sculpturing feature of the walls of a cave, usually formed by solution or by erosion from running water.

Speleology: The science of caves; as against 'karst geomorphology' which also covers surface

landforms. Also used for the general exploration of caves, be it for science or recreation.

Speleothem: A general term for all secondary mineral deposits in a cave. Includes stalactites, stalagmites, flowstone, and crystal growths. Terms such as 'formation' or 'decoration' are sometimes used in a similar manner, but can cause confusion (e.g. with geological formations)

Spring: Where water returns to the surface from an underground karst conduit.

Stalactite: A hanging speleothem formed by dripping of water from a roof.

Stalagmite: A speleothem built up from a floor by water dripping from above. It will commonly have a matching stalactite above, and the two may eventually join to form a column.

Stream-sink (sink): A place where a surface water course disappears underground.

Stygo-: Prefix referring to groundwater habitats and the organisms therein.

Stygofauna: Fauna inhabiting the various types of groundwater - including cave waters. Particular species are called **stygobionts** and can be classified (in analogous manner to the troglobites etc) as follows: A **stygobite** is an obligate aquatic underground species with troglomorphic adaptations, an aquatic equivalent of a (terrestrial) troglobite (q.v.). A **stygophile** is a facultative stygobiont, usually lacking troglomorphies, and considered as the aquatic equivalent of a (terrestrial) troglophile. A **stygoxene** is an habitual aquatic species which spends only part of its life cycle in cave waters and returns periodically to the surface for food.

Thalweg (also **Talweg**): The line of lowest points along a valley floor, normally the stream channel.

Troglobite: An obligate cave-dwelling species, unable to live outside the cave environment; usually with troglomorphic adaptations. The term is usually restricted to terrestrial species, but sometimes aquatic obligates (stygobites, q.v.) may be referred to as aquatic troglobites.

Troglophile: A terrestrial cave-dwelling species which frequently completes its life cycle in caves but is not confined to this habitat. c.f. Stygophile (aquatic species).

Trogloxene: A terrestrial cave-dwelling species which spends only part of its life cycle in caves and returns periodically to the surface for food. c.f. stygoxene (aquatic species)

Vadose: That part of the cave environment that lies above the water table. Also refers to the erosional processes that act in that zone.

Vadose flow: Refers to stream flow within the vadose zone - i.e. a cave stream in contact with air.

Vadose seepage: Refers to water moving downward through the vadose zone, either in narrow fissures, or on the walls of air-filled caves.

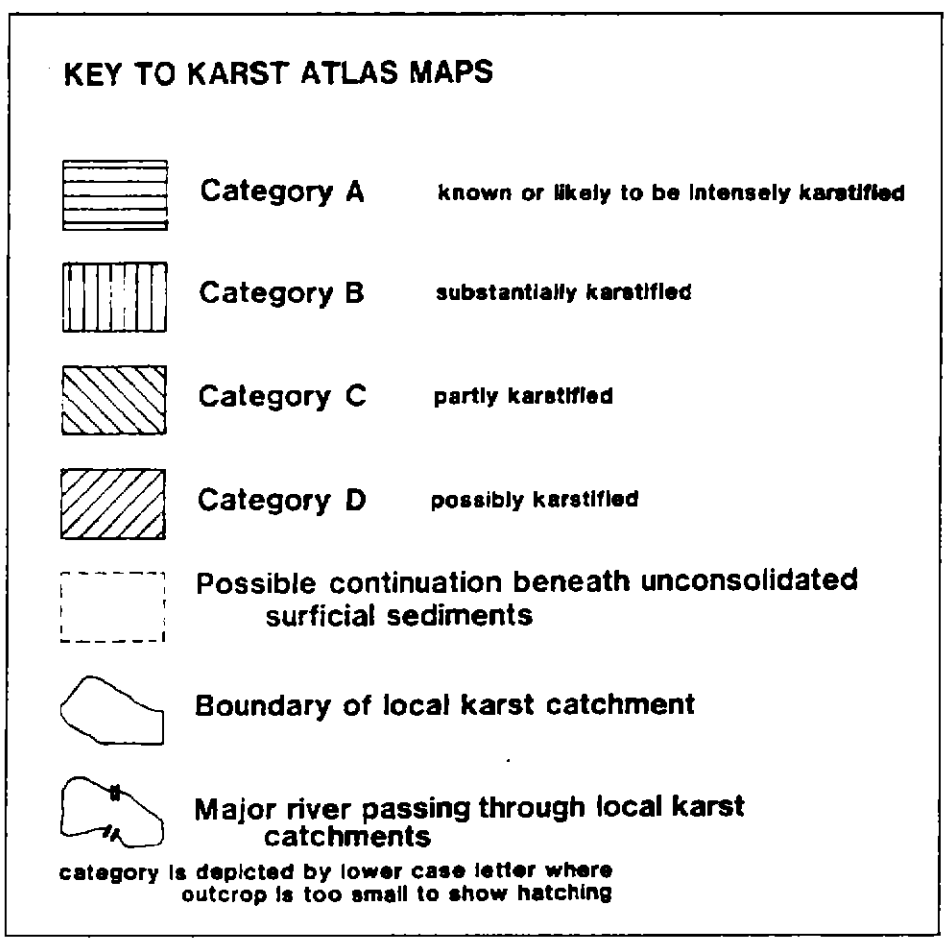
APPENDIX: Alternative Limestone Areas

The following pages are extracts from the ***Atlas of Tasmanian Karst*** (Kiernan, 1995a).

The atlas contains index maps and summary descriptions of all known limestone areas in Tasmania. With assessments of the karst status. It also has useful discussions of a large range of problems that can occur as a consequence of human activities in karst areas - with local examples.

Note that the accuracy of the descriptions and assessments of each area may be limited by the lack of data. For example in some areas the units shown on the geological maps are groups of several lithologies that include limestone, but there is no indication of the extent or location of the limestone beds within the unit. Likewise not all areas have been explored by cavers or karst scientists and so the karst information is limited.

A summary of the main areas in the vicinity of the Hellyer mine is tabled on the next page.

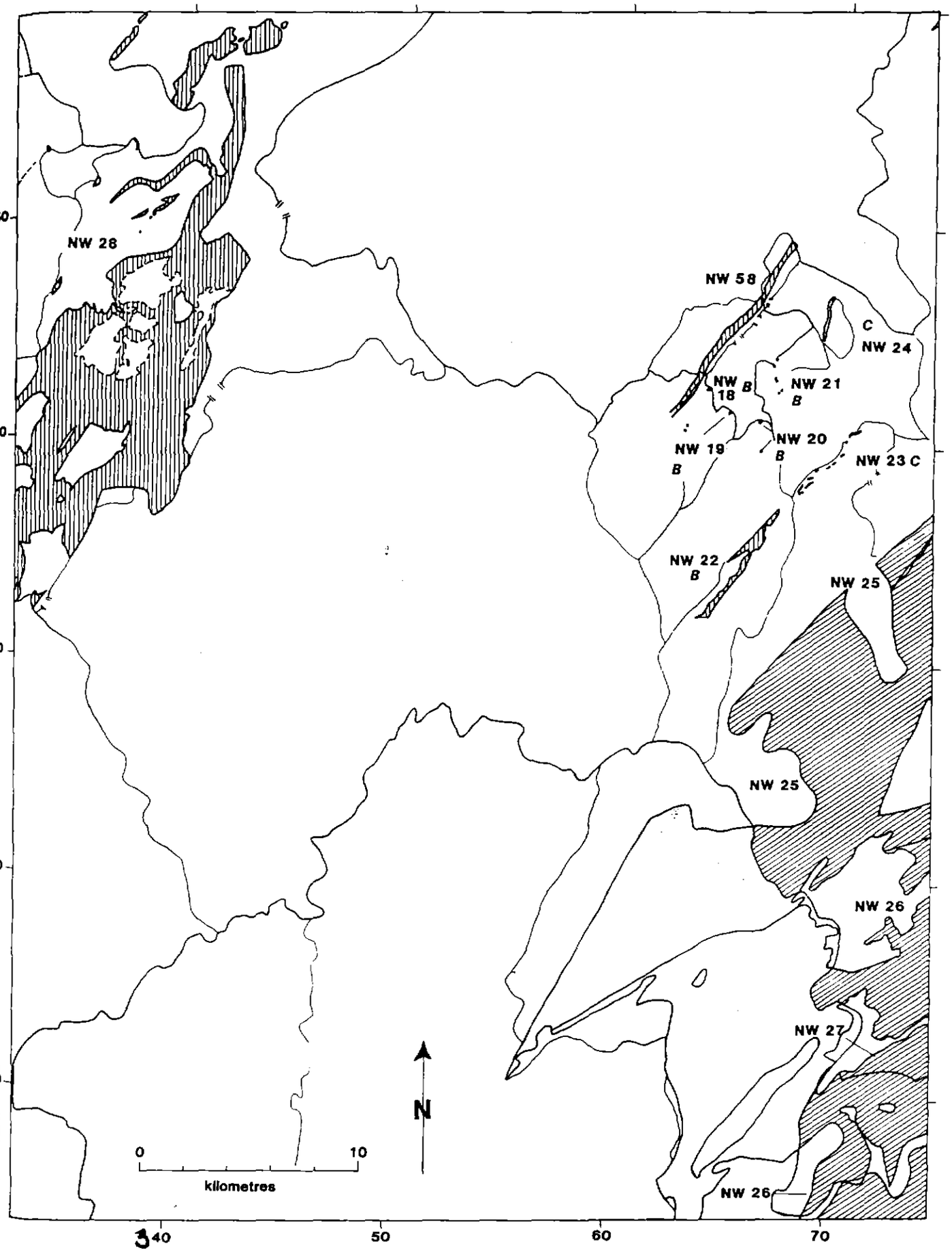


Summary of nearby limestone areas.

Area	Quarry Potential	Karst Significance
NW 25: Hellyer R. - Heazlewood.	Poorly mapped dolomite beds	D: Unknown, probably limited.
NW 26: Luina.	Poorly mapped dolomite beds	D: Unknown, probably limited.
NW 27: Mt. Bischoff.	Poorly mapped dolomite	D: Unknown.
NW 41: Kara (Hampshire)	metamorphosed limestone	C: Little karst
NW 44: Upper Leven.	Gordon Limestone.	C: Partly karstified, possible caves.
NW 45: Loongana.	Gordon Limestone.	A: extensive significant karst.
NW 46: Vale of Belvoir.	Low lying limestone	A: significant karst
NW 49: Lower Lea River.	Small scarn outcrop.	D: Unknown
NW 50: Moina.	Small low-lying limestone area, partly flooded.	C: Minor karst and caves.
NW 51: Bell Creek.	Small low-lying limestone area.	C: Unknown, probably minor.
NW 52: Tin Spur Creek.	Small low-lying limestone.	C: Unknown, limited.
NW 53: Claude Creek.	Small area of impure limestone.	C: Unknown, minimal.
W 7: Brougham River.	Small area of limestone.	B: "substantial karst" = moderately significant
W 8: Charter-Southwell.	Small area of limestone. Partly flooded.	B: "substantial" = moderately significant
W 9: Sophia River.	Small area of limestone. Partly flooded	A: Significant karst
W 10: Mt Cripps	Gordon Limestone.	A: Significant karst.
W 11: Blackwater Ck.	Gordon Limestone	A: Significant karst in the north.
W 12: Dante River	Gordon Limestone	A: Significant karst.

606033

ARTHUR RIVER



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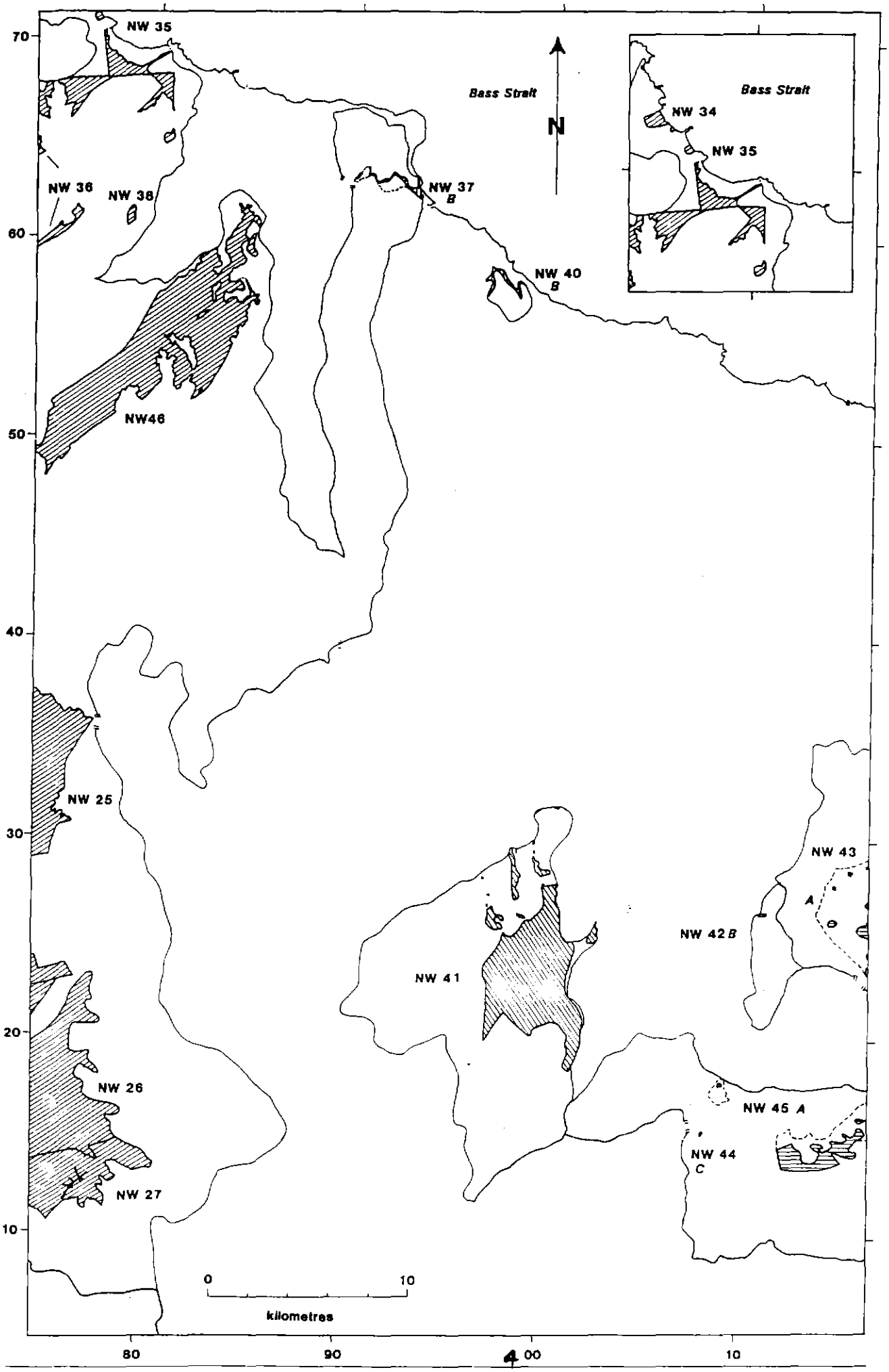
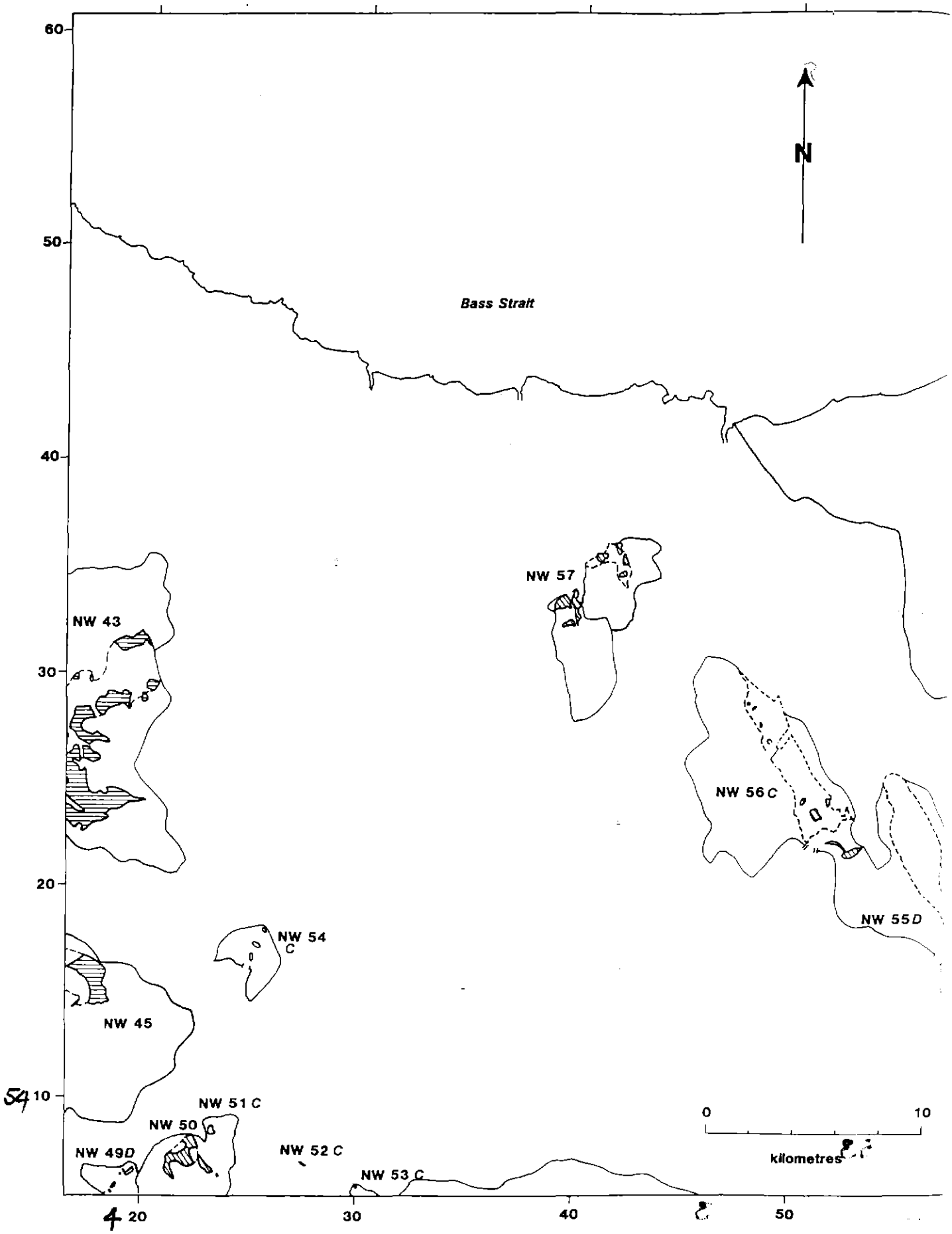
INGLIS 606034



54

93

5 cm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96

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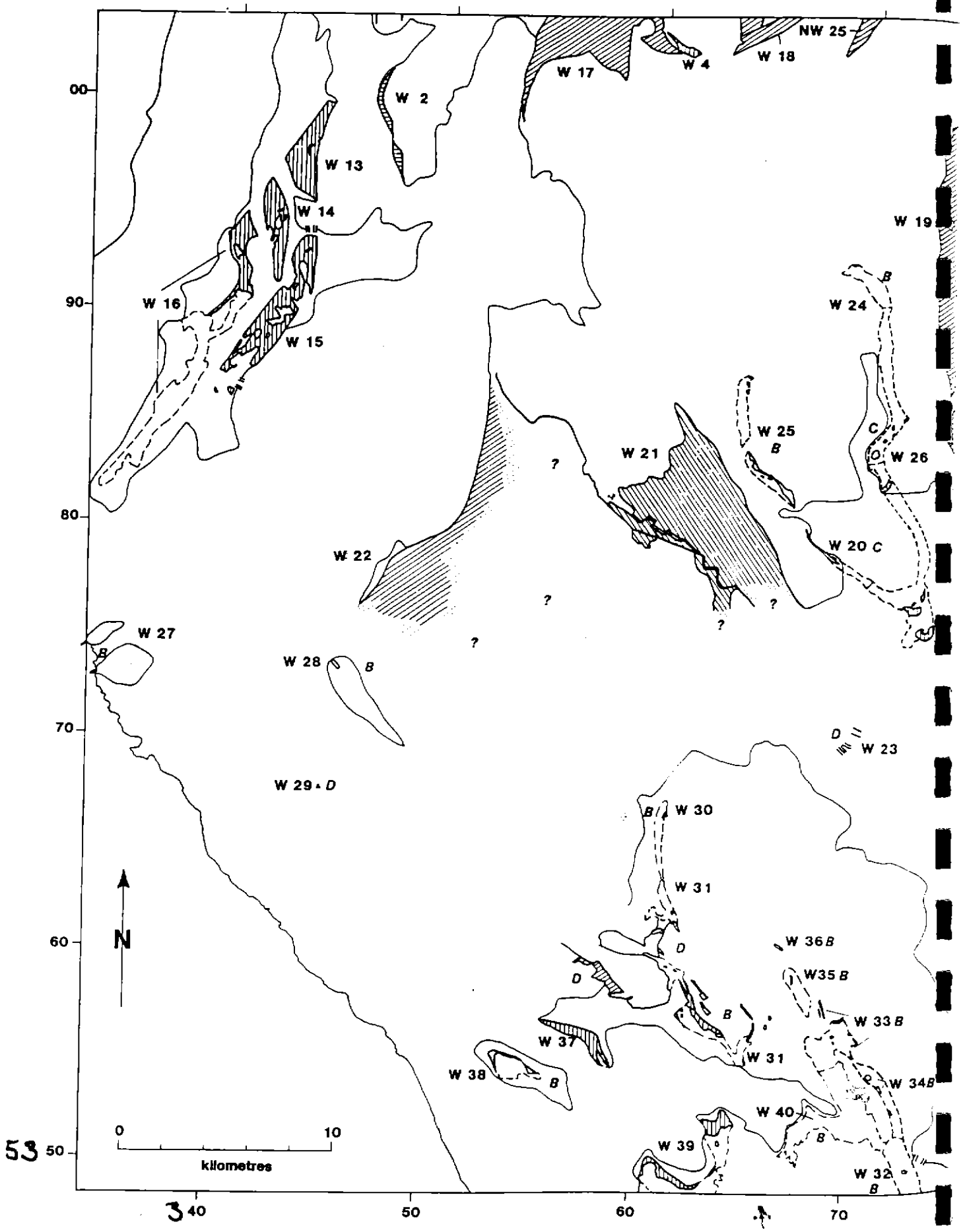
NW 25
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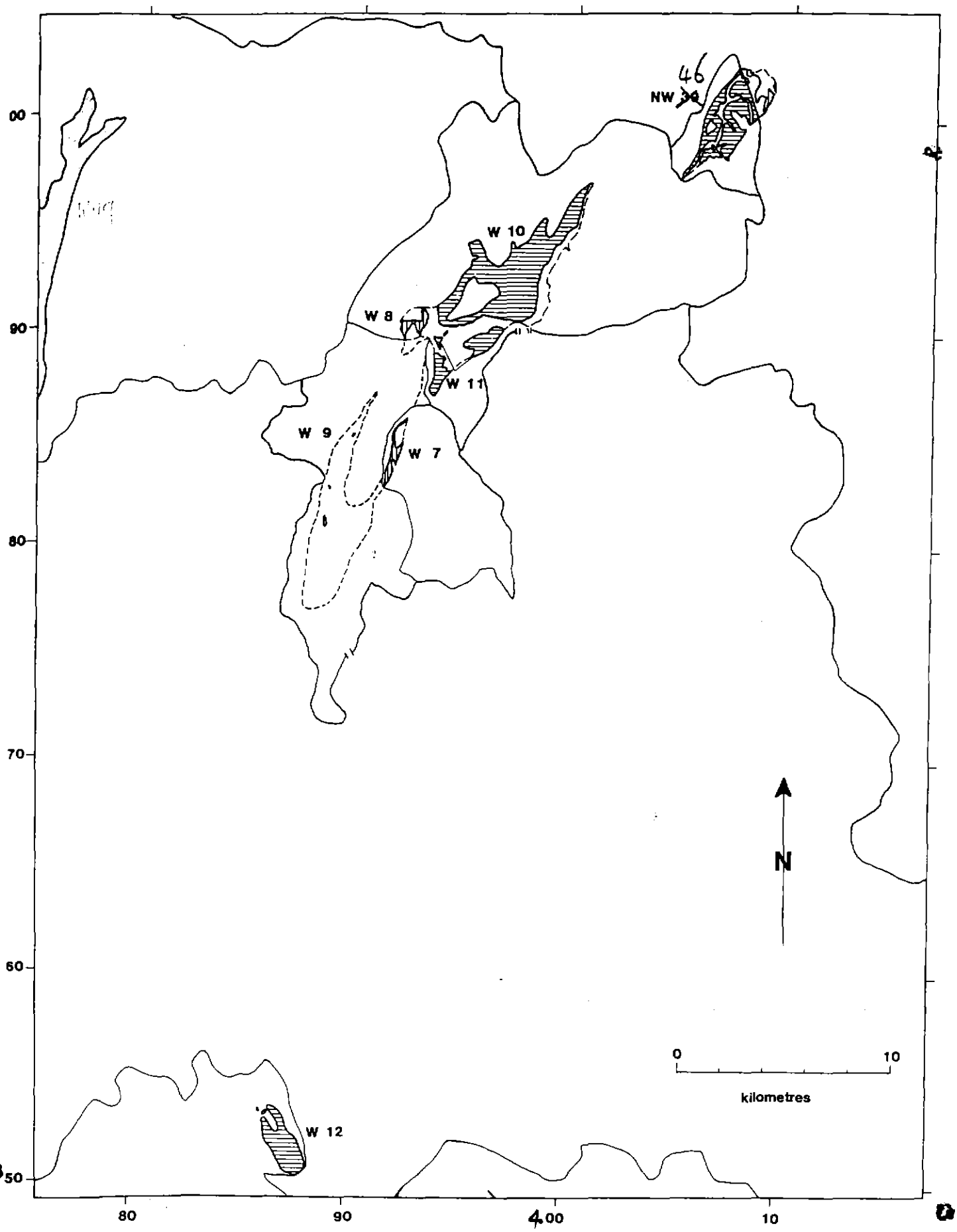
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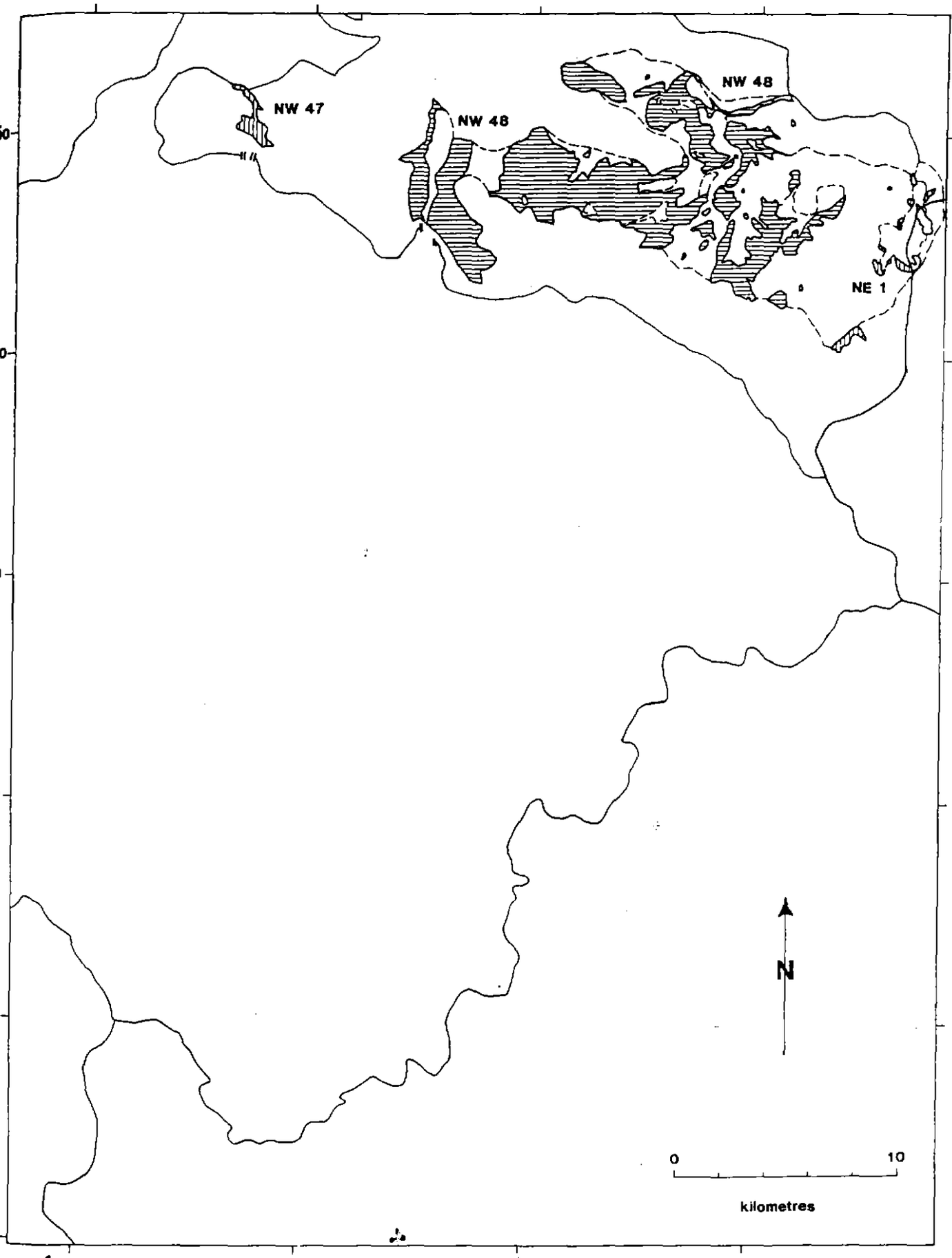

95

5 cm

Topographic sheet: 1: 100 000	Arthur River (at 670 300) and Inglis (at 760 350)
Topographic sheet: 1: 25 000	Keith, Baretop
Geological sheet:	St Valentines 1:50 000, Burnie 1:250 000

SYSTEM CONTEXT

Lithological system/subsystems:	Precambrian dolomite (Oonah Formation)
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2201 mm at Waratah, 25 km to S
Palaeoclimatic	periglacial
Solvent system/s:	normal meteoric, possibly hydrothermal
Denudation system:	mixed autogenic and allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	140-620 m a.s.l.
Extent of outcrop:	>60 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping; interstratal?

KARST EXTENT & INVESTIGATIONS

Karst development:	not confirmed
Documentation:	nil
Number of investigation trips:	nil
Investigators:	n/a
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	limited
Caves:	limited
Land tenure:	Crown
Management issues:	unknown
Category:	D

FURTHER INFORMATION

A large area of Oonah Formation rocks extends southwestwards from the confluence of the Hellyer and Arthur Rivers. These form the upper subdivision of the Oonah Formation rocks, known to be dolomite bearing and potentially karstic (Sharples 1992b:106). Dolomite is known to occur in the Hellyer River area. On the basis of present knowledge, the sites at which dolomite occurs cannot all be precisely delineated on the Karst Atlas maps, nor even the localities in which the carbonate-bearing rocks of the upper subdivision of the Oonah Formation occur.

Topographic sheet: 1: 100 000	Arthur River (at 650 060)
Topographic sheet: 1: 25 000	Luina
Geological sheet:	Brown 1986

SYSTEM CONTEXT

Lithological system/subsystems:	EoCambrian dolomite (Success Creek Group - Ecc)
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2201 mm at Waratah, 13 km to ENE
Palaeoclimatic	periglacial
Solvent system/s:	normal meteoric (and hydrothermal?)
Denudation system:	mixed autogenic and allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	-600 m a.s.l. (total ECC)
Extent of outcrop:	>50 km² (total ECC)
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	not confirmed
Documentation:	nil
Number of investigation trips:	nil
Investigators:	n/a
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	unknown but probably very limited
Caves:	very limited
Land tenure:	Crown
Management issues:	unknown
Category:	D

FURTHER INFORMATION

This is an extensive area of Success Creek Group rocks, a formation known to contain carbonate beds. However, these are localised and hence potential karst is likely to be very much less extensive than outcrops of the host formation. The carbonate in this unit usually involves very thin beds of silicified rock in this area, hence the potential for karst is very limited. The Success Creek Group rocks are overlain to the east by Tertiary basalt, hence if any karst is developed it could also occur in an interstratal situation beneath the basalt.

The Cleveland tin-copper deposit was produced by metasomatic replacement of limestone in the Hall Formation of Cambrian age (Burrett and Martin 1989).

MT BISCHOFF NW 27

Topographic sheet: 1: 100 000	Inglis (at 765 125)
Topographic sheet: 1: 25 000	Waratah, Guildford, Luina
Geological sheet:	St Valentines 1:50 000

SYSTEM CONTEXT

Lithological system/subsystems:	Precambrian dolomite (Oonah Formation)
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2201 mm at Waratah, 2 km to S
Palaeoclimatic	periglacial
Solvent system/s:	hydrothermal and normal meteoric
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	350-450 m a.s.l.
Extent of outcrop:	<1 km² and 5 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	not confirmed
Documentation:	nil
Number of investigation trips:	nil
Investigators:	n/a
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	unknown
Caves:	unknown
Land tenure:	Crown (mining lease)
Management issues:	mining
Category:	D

FURTHER INFORMATION

Dolomitic rocks in this area include finely laminated dolomite with interstitial quartz, pure dolomite and thin-bedded dolomitic shales.

The tin ore bodies in this area have formed both by metasomatic replacement of dolomite beds and as vein-style deposits. A 40-60 m thick dolomite bed has been partly replaced (Collins *et al.* in Burrett and Martin 1989: 279). The dolomites represent the upper subdivision of the Oonah Formation (Sharples 1992a:106).

The dolomite occurs at the surface just north of the Waratah River and on the southern side of Mt Bischoff. Near the peak of Mt Bischoff sulphides that carry cassiterite have largely replaced the dolomite, the latter having mostly been eroded from the mineralised area but preserved in synclinal troughs (Solomon, in Spry and Banks 1962, figures 54 and 55).

The dolomite has not been differentiated in existing geological mapping of the area hence the broader area of Oonah Formation rocks known in this area is depicted on the Karst Atlas map.

Topographic sheet: 1: 100 000	Inglis (at 990 240)
Topographic sheet: 1: 25 000	Parrawe, Loyetea, Loongana, Guildford, Tewkesbury, Riana
Geological sheet:	St Valentines 1:50 000

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2201 mm at Waratah, 25 km to SW
Palaeoclimatic	periglacial
Solvent system/s:	normal meteoric possible hydrothermal?
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	flank and plain
Altitudinal range:	500-620 m a.s.l.
Extent of outcrop:	~26 km²
Past variation:	part covered by basalt
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	only minor karren recognised to date
Documentation:	nil
Number of investigation trips:	3
Investigators:	cavers and geomorphologists
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	some
Caves:	unknown
Land tenure:	private
Management issues:	mining, logging
Category:	C

FURTHER INFORMATION

Carbonate-rich sediments occur extensively in this area but have been subject to considerable contact metamorphism in response to the intrusion of granite. The limestone has been silicified and the principal outcrop is of chert or hornfels that contains bands of limestone and calc-silicate bands composed mainly of wollastonite (Table NW 41 - 1). The limestone occurs as one principal outcrop of more than 20 km² and at least nine much smaller areas within 4 km to the north and north-east. Older non-carbonate Ordovician rocks occur to the east and west, while in the south lies a fault-bounded block of Devonian sandstone and mudstone (a correlate of the Bell Shale). The limestone is directly overlain by Tertiary basalt at one point on its southern margin, while the smaller limestones occurrences to the north are in all but one case exposed through windows in the limestone hence interstratal karst is possible. Mining for tin, wollastonite and tungsten have taken place.

Most of the area is of low relief, approaching 80 m around Highwood Hill. Quaternary age surficial deposits are widespread and there is generally little exposure of the bedrock. However, on Highwood Hill the terrain is steep and rocky with little soil cover. The limestone exposed here forms small blocky outcrops with some incipient karren.

Topographic sheet: 1: 100 000	Inglis (at 082 154)
Topographic sheet: 1: 25 000	Loongana
Geological sheet:	MRV Map 8-Mt Catley/Mt. Tor (part), St Valentines 1:50 000

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1662 mm at Erriba, 20 km to E
Palaeoclimatic	glacial, glaciofluvial and periglacial
Solvent system/s:	normal meteoric
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	flank and plain
Altitudinal range:	280-300 m a.s.l.
Extent of outcrop:	<0.5 km² but possible further limestone beneath Quaternary sediments and Tertiary basalt
Past variation:	-
Exposure style system:	caprock retreat with possible down-dip stripping; prekarstified?

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	nil
Number of investigation trips:	1
Investigators:	*geomorphologist*
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	probable
Caves:	possible
Land tenure:	private?
Management issues:	unknown
Category:	C

FURTHER INFORMATION

Gordon Group limestone crops out on the Leven River ~5 km west of the margin of the Loongana karst at the eastern edge of Frosts Flats. The intervening terrain comprises hill slopes of basalt or mantled by Quaternary sediments including possible till and the floor of the Leven Valley which is mantled by alluvium and glaciofluvial sediments. The possibility exists that limestone extends continuously beneath the basalt and Quaternary sediments to the upper Leven area but this cannot be proven at this time. The presence of sinkholes formed in basalt ~2 km north of the outcrop on the Leven River itself indicates that limestone is present beneath the basalt in at least one locality and that interstratal karst is present. The sinkholes probably reflect the fact that the basalt caprock is permeable, but the possibility also exists that the limestone was karstified prior to extrusion of the basalt.

Topographic sheet: 1: 100 000	Forth (at 165 170) and Inglis (at 150 150)
Topographic sheet: 1: 25 000	Loongana, Wilmot
Geological sheet:	MRV Map 8. Mt Catley -Mt Tor

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1662 mm at Erriba, 15 km to E
Palaeoclimatic	glacial, glaciofluvial and periglacial
Solvent system/s:	normal meteoric
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	flank and plain
Altitudinal range:	300-470 m a.s.l.
Extent of outcrop:	24 km^2
Past variation:	part covered by lava flows
Exposure style system:	caprock retreat and downstream stripping; prekarstified

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	good
Number of investigation trips:	>10
Investigators:	cavers and geomorphologists
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	yes
Caves:	yes
Land tenure:	predominantly private
Management issues:	siltation, damage to mound springs, unmanaged public entry; hydro electric development?
Category:	A

FURTHER INFORMATION

This area lies 12 km south of Gunns Plains in the valley of the Leven River. Descriptions have been provided by Kiernan (1978b) and S. Eberhard (1992). The limestone occurs in a synclinal trough, overlies sandstones and conglomerates and is faulted against Cambrian slates to the west. Tertiary basalt overlies the limestone in places, raising the possibility of interstratal karst being present including possible pre-basalt karst. The limestone is reasonably pure (Table NW 45 - 1.)

Rounded forms of karren predominate among the surface solution sculpture assemblage. A few streamsinks are known with resurgences and exsurgences including mound springs and open cave entrances. Some warm springs are present. Downstream of Loongana the Leven enters Leven Canyon, a spectacular non-carbonate gorge hundreds of metres deep, the upstream portal to which is an impressive limestone defile. About 15-20 caves are known, the longest of which contains ~700 m of passages.

Subfossil bone deposits occur in some caves. The caves contain a rich invertebrate fauna with 46 species recorded including seven troglobites. This area has the highest recorded diversity of cavernicolous amphipods in the state, represented by three genera and five species (Eberhard *et al* 1991).

Management issues include the impacts of land clearing including forestry operations in the karst catchments, accelerated sinkhole formation and road construction including incipient sinkhole formation, the presence of a major cave passage just beneath the road, and an HEC pole planted in a pothole.

Table NW 45 -1
Limestone analysis from Loongana in %, (N=7)
(from Hughes, 1957).

Acid insol.	3.2-11.6
Fe_2O3 & Al_2O_3	0.4-1.0
CaO	47.2-52.9
$CaCO_3$	86.2-94.4
MgO	1.2-2.5
$MgCO_3$	2.5-5.2

Topographic sheet: 1: 100 000	Sophia (at 075 995)
Topographic sheet: 1: 25 000	Lea, Pencil Pine
Geological sheet:	Mackintosh 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2774 mm at Cradle Valley, 10 km to SSE
Palaeoclimatic	glacial and periglacial
Solvent system/s:	normal meteoric
Denudation system:	mixed autogenic and allogenic
Topographic system -	
Contemporary:	plain
Altitudinal range:	800-920 m a.s.l.
Extent of outcrop:	12-14 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	poor
Number of investigation trips:	>10
Investigators:	geomorphologists
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	limited
Caves:	unlikely
Land tenure:	private
Management issues:	roading, surface view fields, possible sewage disposal from tourist venture
Category:	A

FURTHER INFORMATION

This very scenic area comprises a broad valley floored by limestone that is mantled by glacigenic sediments of pre Last Interglacial age (Kiernan 1988c, 1990b). This is one of the most distinctive karsts in Tasmania, with its open, windswept rolling grassland dimpled by sinkholes and sinkhole lakes, and for many people one of the State's most attractive karsts. It was first recorded and named by Surveyor Fossey from the Van Diemans's Land Co. in April 1828 (Meston 1958) while Backhouse (1843:125) reported having "crossed a fine open country called the Vale of Belvoir, in which there is a sheet of water named Patterdale Lake [now known as Lake Lea]. The vale has numerous pits of water and streams, even with the grass, dividing and again uniting, so as to make travelling difficult. There are also deep fissures in the earth, destitute of water".

A large number of cover collapse sinkholes and sinkhole ponds exist. Most of the surface karst is easily visible due to the nature of the vegetation, but given an absence of detailed study the full range of sinkhole species, other land forms present, and related karst fauna, flora and potential palynological sites is yet to be unravelled. No caves have been recorded.

Possible construction complications with the Cradle Mountain link road were recognised in the Environmental Impact Study for that project. Predictions of likely collapse problems some years after construction proved correct and one major failure of the road has already occurred (Kiernan 1989m).

Topographic sheet: 1: 100 000	Forth (at 195 068)
Topographic sheet: 1: 25 000	Lea
Geological sheet:	Sheffield 1:63 360, Hughes 1957; MRV Map 8 Mt Catley/Mt Tor

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1662 mm at Erriba, 8 km to NE
Palaeoclimatic	periglacial
Solvent system/s:	normal meteoric and possible hydrothermal
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	500-760 m a.s.l.
Extent of outcrop:	<0.5 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping, possibly localised down-dip stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	unconfirmed
Documentation:	nil
Number of investigation trips:	nil
Investigators:	n/a
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	unknown
Caves:	unknown
Land tenure:	private
Management issues:	unknown
Category:	D

FURTHER INFORMATION

Hughes (1957) indicates a small isolated outcrop of limestone 1.5 km west of the Moina karst in the valley of the Lea River, but it is not depicted on the Sheffield sheet produced by the Tasmanian Department of Mines. More recent mapping undertaken as part of the Mt.Read volcanics project indicates predominantly skarn after Gordon Group limestone, occurring as five separate outcrops. The skarn is of Devonian age. raising the possibility of filled palaeokarst cavities being present. In at least one case the skarn occurs as a window in the overlying basalt raising the possibility that exposure has been by caprock retreat and down-dip rather than down stream stripping, which would imply karstification.

Topographic sheet: 1: 100 000	Forth (at 220 075)
Topographic sheet: 1: 25 000	Cethana
Geological sheet:	Sheffield 1:63 360 & MRV Map 8, Mt Catley - Mt Tor.

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	Fold structure province
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1622 mm at Erriba, 5 km to NE
Palaeoclimatic	periglacial, possibly glacial
Solvent system/s:	normal meteoric and possible hydrothermal
Denudation system:	mixed allogenic and autogenic
Topographic system -	
Contemporary:	valley floor
Altitudinal range:	380-600 m a.s.l.
Extent of outcrop:	<2 km²
Past variation:	mantled by Quaternary surficial sediments
Exposure style system:	caprock retreat and downstream stripping with localised down-dip stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	moderate
Number of investigation trips:	~5
Investigators:	cavers
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	minor potential
Caves:	minor potential
Land tenure:	private
Management issues:	flooded in hydro electric impoundments
Category:	C

FURTHER INFORMATION

This small area occupies a broad valley-bottom area where the bedrock is heavily mantled by Quaternary surficial sediments. Much of the outcrop has been inundated by a hydro electric impoundment known as Lake Gairdner but a significant proportion has been known to be revealed at times when the level of the storage is low. Upstream on Bismuth Creek and on Ti Tree Creek the limestone has been metamorphosed to skarn (Table NW 50 - 1).

Surface solution sculpture has been exposed in areas cleared for pasture and in areas of the Lake Gairdner storage. Some small dry valleys are also present. Bismuth Creek maintains a surface course across the limestone, but a few hundred metres to the west a small stream sinks into the limestone via a subjacent karst collapse sinkhole and a small cave (M201) which is inhabited by glow-worms (Kiernan 1979a).

Other small caves in the banks of the Iris river near the road bridge were reported by Goede (1968). These were believed to have been flooded by the storage, but inspection has revealed them to be above water level most of the time.

606049

Table NW 50 -1
Limestone analysis from Moina
(from Hughes 1957)

		Iris R. bridge	*Above Iris-Lea confluence*
Acid Insol.	(%)	61.8	9.2
Fe_2O_3 & Al_2O_3	(%)	6.1	2.2
CaO	(%)	16.7	47.0
MgO	(%)	0.9	2.9
Ignition loss	(%)	1.3.9	38.6

Topographic sheet: 1: 100 000	Forth (at 232 085)
Topographic sheet: 1: 25 000	Cethana
Geological sheet:	Sheffield 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1662 mm at Erriba, 4 km to NE
Palaeoclimatic	periglacial
Solvent system/s:	normal meteoric
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	490-500 m
Extent of outcrop:	0.3-0.4 km^2
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	not confirmed
Documentation:	nil
Number of investigation trips:	1
Investigators:	geomorphologist
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	minor
Caves:	unlikely
Land tenure:	private and Crown
Management issues:	mineral exploration
Category:	C

FURTHER INFORMATION

This small area of limestone lies ~1 km NE of the Moina area, being separated from it by Bell Mountain. The limestone is generally surrounded by older non-carbonate sediments of the Moina Formation but Tertiary basalt forms the summit of Bell Mountain. Limestone also occurs in the last 50 m of the long water tunnel at the Round Hill Mine (McIntosh Reid 1919).

The topographic relief of the limestone in this area is very low and much of the outcrop has been swamped by surficial sediments of Quaternary age.

TIN SPUR CREEK NW 52

Topographic sheet: 1: 100 000	Forth (at 276 068)
Topographic sheet: 1: 25 000	Cethana
Geological sheet:	Sheffield 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1662 mm at Erriba, 4 km to NW
Palaeoclimatic	periglacial, glacial
Solvent system/s:	normal meteoric
Denudation system:	allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	~200-320 m a.s.l.
Extent of outcrop:	<0.5 km^2
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	not confirmed
Documentation:	nil
Number of investigation trips:	nil
Investigators:	n/a
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	limited potential
Caves:	very limited potential
Land tenure:	Crown
Management issues:	unknown
Category:	C

FURTHER INFORMATION

This small area is surrounded by Ordovician Moina Formation rocks. The limestone occurs along the stream.

Topographic sheet: 1: 100 000	Forth (at 300 060)
Topographic sheet: 1: 25 000	Cethana
Geological sheet:	Sheffield 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	1662 mm at Erriba, 7 km to NW
Palaeoclimatic	periglacial
Solvent system/s:	normal meteoric
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	valley floor
Altitudinal range:	420–440 m a.s.l.
Extent of outcrop:	<0.3 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed minor
Documentation:	nil
Number of investigation trips:	1
Investigators:	geomorphologist
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	negligible
Caves:	very unlikely
Land tenure:	Crown
Management issues:	none known
Category:	C

FURTHER INFORMATION

This very small area of limestone occurs along either bank of Claude Creek for a distance of ~200 m. The limestone is relatively impure (Table NW 53 - 1 and NW 53 - 2). A further occurrence lies in the No. 3 Adit (water tunnel) of the old Round Hill Mine, where interstratal karst is present (Hughes 1957).

Minor surface solution sculpture is present at the Claude Creek site.

Table NW 53 - 1
Limestone analysis from Claude Creek
(from Hughes 1957)

		Claude Creek (upper site)	*Claude Creek (lower site)*
Acid insol.	(%)	26.0	25.9
Fe_2O_3&Al_2O_3	(%)	2.8	3.5
CaO	(%)	38.6	36.6
MgO	(%)	1.2	2.5
Ignition loss	(%)	31.2	31.7

Table NW 53 - 2
Analysis of single limestone bed, Claude Creek
(from Hughes 1957)

SiO_2	%	10.12
Al_2O_3	%	1.45
Fe_2O_3	%	2.29
MnO	%	0.03
P_2O_3	%	0.03
CaO	%	43.50
MgO	%	3.81
Ignition loss	%	38.04

BROUGHAM RIVER (Whitehawk Creek) W 7

Topographic sheet: 1: 100 000	Sophia (at 920 840)
Topographic sheet: 1: 25 000	Block
Geological sheet:	Mackintosh 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2774 mm at Cradle Valley, 20 km to ENE
Palaeoclimatic	glacial and periglacial
Solvent system/s:	normal meteoric
Denudation system:	mixed allogenic and autogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	200-600 m a.s.l.
Extent of outcrop:	3 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	poor
Number of investigation trips:	1
Investigators:	archaeologists
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	probable
Caves:	possible
Land tenure:	Crown
Management issues:	erosion of archaeological site by HEC reservoir.
Category:	B

FURTHER INFORMATION

This area lies 3.5-5.2 km SSW of the Blackwater Creek area south of Mt Cripps. The intervening area is capped by Tertiary basalt beneath which it is probable that the limestone is continuous. Interstratal karst between the two areas is possible. Unconsolidated Quaternary sediments mantle the limestone over part of this area.

Investigation of the karst in this area has been limited to prospecting by archaeologists for sites of possible aboriginal occupation, and some more recent preliminary searching for caves by members of the Savage River Caving Club. White Horse Creek sinks underground into a cave with many glow-worms (~918845) and other small caves are known (B. Dutton pers. comm.). Archaeological deposits have been recorded from a cave in a medium-sized limestone bluff on the lower part of the Brougham River, partially inundated through the filling of the artificial hydro-electric reservoir known as Lake Mackintosh (Allen *et al.* 1990).

Topographic sheet: 1: 100 000	Sophia (at 925 900)
Topographic sheet: 1: 25 000	Charter, Block
Geological sheet:	Mackintosh 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2274 mm at Cradle Valley, 19 km to E
Palaeoclimatic	glacial, glacio-fluvial, periglacial
Solvent system/s:	normal meteoric
Denudation system:	mixed allogenic and autogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	220-300 m a.s.l.?
Extent of outcrop:	>2 km²
Past variation:	part buried by Quaternary sediments
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	not confirmed
Documentation:	nil
Number of investigation trips:	nil
Investigators:	n/a
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	unknown but probable
Caves:	unknown but probable
Land tenure:	Crown
Management issues:	part inundated by artificial reservoir
Category:	B

FURTHER INFORMATION

Geologically this area represents a westward extension of the Mt Cripps and Blackwater Creek areas but it has been isolated through the filling of the artificial Lake Mackintosh storage.

Limestone crops out over ~2 km² but also occurs on the opposite (eastern) side of the Southwell Valley in the Mt Cripps area, and on the valley floor 2.5 km further upstream. Extensive areas of the Southwell Valley are mantled by glacigenic sediments and it is probable that at least part of the terrain is underlain by limestone and karstic aquifers.

Outflows from any cave systems may have been inundated due to the filling of the Lake Mackintosh reservoir.

Topographic sheet: 1: 100 000	Sophia (at 886 814)
Topographic sheet: 1: 25 000	Block
Geological sheet:	Mackintosh 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2444 mm at Zeehan, 30 km to SW
Palaeoclimatic	glacial
Solvent system/s:	normal meteoric
Denudation system:	predominantly autogenic
Topographic system -	
Contemporary:	plain
Altitudinal range:	180-210 m a.s.l.
Extent of outcrop:	<1 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	nil
Number of investigation trips:	<5
Investigators:	HEC personnel
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	yes
Caves:	yes
Land tenure:	State Reserve
Management issues:	inundated by artificial Lake Mackintosh reservoir
Category:	A

FURTHER INFORMATION

Two outcrops of limestone are indicated on the Mackintosh sheet, the larger on the Sophia River ~2 km upstream of its confluence with the Mackintosh River, the smaller ~0.6 km upstream from the confluence on the Mackintosh River. A much larger area of ~20 km² exhibits similar topography, suggesting that at least part of it may be underlain by limestone. The area is heavily mantled by Quaternary sediments including till and glaciofluvial deposits, there being a small limestone outcrop another 2 km north. The possibility that limestone underlies the Quaternary sediments all the way to the Brougham Creek (Whitehawk Creek) karst cannot be discounted.

Sinkholes and caves have been visited in this general area (R. Boyle pers. comm.). However, the site has since been inundated with the filling of the artificial hydro-electric reservoir now known as Lake Mackintosh.

Topographic sheet: 1: 100 000	Sophia (at 990 950)
Topographic sheet: 1: 25 000	Charter, Pencil Pine
Geological sheet:	Mackintosh

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2050 mm at Que River Mine, 4 km to NW
Palaeoclimatic	glacial and periglacial
Solvent system/s:	normal meteoric
Denudation system:	mixed autogenic and allogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	230-500 m a.s.l.
Extent of outcrop:	>20 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	~100 caves, numerous sinkholes known, polygonal karst
Documentation:	excellent - Savage River Caving Club
Number of investigation trips:	>100
Investigators:	Savage River Caving Club
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	considerable
Caves:	yes
Land tenure:	Crown
Management issues:	visitor management, considerable part drowned in reservoir, future logging?
Category:	A

FURTHER INFORMATION

This highly karstified limestone area lies in the upper Mackintosh River Valley on the southern and eastern side of Mt Cripps, between the valleys of the Vale River and the Southwell River. At ~20 km² this limestone area is relatively extensive and its topographic relief of up to 300 m has contributed to the development of many karst features (Mann 1971, Jackson 1984, Shannon *et al.* 1991). The lower part of most systems has probably been drowned by filling of the artificial hydro-electric reservoir now known as Lake Mackintosh. The area has been repeatedly glaciated during the late Cainozoic (Augustinus 1984, Kiernan 1990b) and this may have contributed to some of the complexities of its karst morphology.

An area of very well developed polygonal karst exists. The first cave discoveries were made by forestry survey parties. Caves up to 125 m deep and 500 m in length have been documented (Shannon *et al.* 1991). Paragenetic modification is common. Significant clastic speleothems are present in some caves, notably Philrod Cave. Carbonate speleothems include impressive flowstones in Snowy Mountain Cave (Figure 4.6) and a straw stalactite 4.4 m long in Philrod Cave.

North Forest Products halted operations in the area following location of the karst, and has fostered exploration and documentation of the area by the Savage River Caving Club as an aid to the company's planning.

The Backwater Creek area south of the Mackintosh River, and the Mt Charter-Southwell area on the opposite side of Southwell River, are probably geologically part of the same karst area. However, they are considered separately in this Atlas due to their artificial isolation following the filling of Lake Mackintosh.

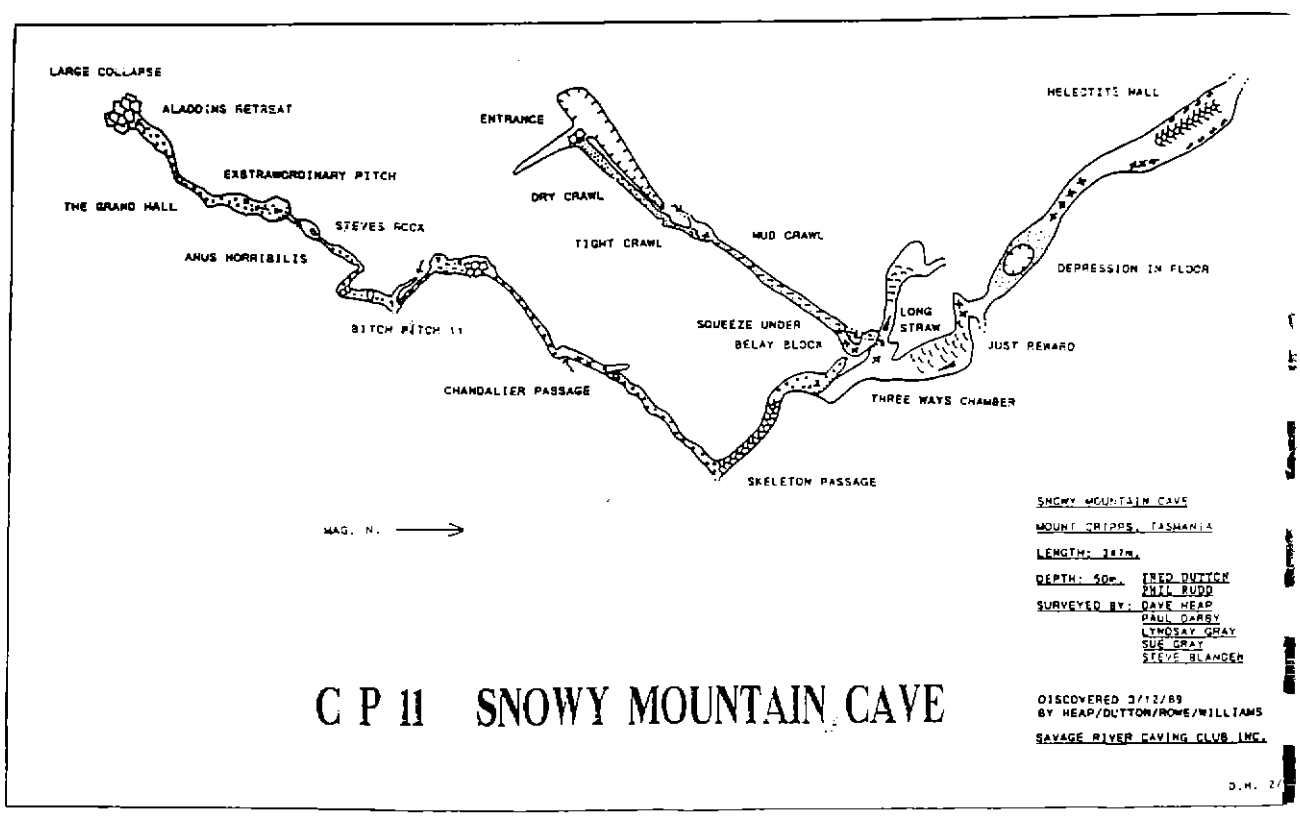

Figure 4.6 Map of Snowy Mountain Cave, courtesy Savage River Caving Club.

BLACKWATER CREEK W 11

Topographic sheet: 1: 100 000	Sophia (at 940 880)
Topographic sheet: 1: 25 000	Block, Charter
Geological sheet:	Mackintosh 1:63 360

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2050 mm at Que River Mine, 6 km to NW
Palaeoclimatic	fluvial
Solvent system/s:	normal meteoric
Denudation system:	mixed allogenic and autogenic
Topographic system -	
Contemporary:	flank
Altitudinal range:	220-580 m a.s.l.
Extent of outcrop:	7-8 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	fair
Number of investigation trips:	2
Investigators:	cavers and geomorphologists
Visited during Atlas compilation:	yes
Potential for further discoveries-	
Surface karst landforms:	yes
Caves:	yes
Land tenure:	Crown
Management issues:	visitor impacts, drowning by artificial reservoir
Category:	A

FURTHER INFORMATION

This area represents a southward extension of the Mt Cripps karst but is now isolated from it due to the filling of the artificial hydro-electric reservoir known as Lake Mackintosh. Three principal limestone outcrops occur, with the intervening area being mantled by glacigenic sediments of Quaternary age (Kiernan 1990b).

Only that part of the outcrop downstream from Fury Flats has been investigated for karst, and in this area sinkholes and some caves have been found. The Sanctuary is an impressively decorated cave with some damage reportedly already caused by over-enthusiastic cavers, and its proximity to the lake and potential boat access means it is at some risk of further damage (Figure 4.7). The remainder of the limestone remains unexplored as far as karst and possible caves are concerned. The hill that contains the Sanctuary was burnt out by a wildfire that crossed the Mackintosh hydro-electric impoundment through the tops of the drowned trees in early 1995.

Topographic sheet: 1: 100 000	Sophia (at 870 520)
Topographic sheet: 1: 25 000	Tyndall
Geological sheet:	Queenstown 1:250 000

SYSTEM CONTEXT

Lithological system/subsystems:	Gordon Group limestone
Structural system/subsystems:	folded and faulted
Climato-geomorphic systems-	
Contemporary:	fluvial
Annual rainfall/station:	2450 mm at Queenstown, 12 km to SW
Palaeoclimatic	glacial, glaciofluvial and periglacial
Solvent system/s:	normal meteoric
Denudation system:	predominantly allogenic
Topographic system -	
Contemporary:	plain and flank
Altitudinal range:	550-680 m a.s.l.
Extent of outcrop:	5 km²
Past variation:	-
Exposure style system:	caprock retreat and downstream stripping

KARST EXTENT & INVESTIGATIONS

Karst development:	confirmed
Documentation:	good
Number of investigation trips:	<10
Investigators:	caves and geomorphologists
Visited during Atlas compilation:	no
Potential for further discoveries-	
Surface karst landforms:	yes
Caves:	possible
Land tenure:	Crown
Management issues:	unknown
Category:	A

FURTHER INFORMATION

The upper reaches of the Dante Rivulet Valley are occupied by a broad synclinal outcrop of well bedded, shaley and impure limestone. The limestone is surrounded by slopes formed on older Ordovician conglomerates and quartz sandstone. Glacial erratic boulders of Owen conglomerate up to 6 m in diameter occur on the limestone. Residual blades of limestone up to 3 m high are present which, given the low gradient of the terrain, are unlikely to be entirely postglacial phenomena. The most dramatic feature is a limestone gorge up to 30 m deep and often less than 5 m wide. Caves up to 5 m in diameter interrupt the surface gorge in several places. Close to a dozen caves are known (Kiernan 1981a).