

1980/5 Mineralogical investigation of samples from clay member, Barnes Hill

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*Abstract*

Samples from chromite recovery tests and originating from costeans in the Tertiary clay member, beneath the chromite-bearing sand horizon at Barnes Hill, were examined by X-ray diffraction, optical and electron microprobe techniques. The major components present are chrome-bearing aluminous goethite, chamosite and kaolin (both containing a small amount of Cr<sub>2</sub>O<sub>3</sub>). Opaque oxides are magnetite and high-chrome chromian spinel. Minor accessory minerals are quartz, opaline silica and zircon, rutile and ilmenite.

INTRODUCTION

X-ray diffraction techniques were of limited use because of the poorly crystalline nature of the goethite and chamosite and the limited amount of chromite present. Optical examination, prior to microprobe analysis, tended to over-estimate the amount of spinel phase present (see interim report, 1 February, 1980) and described the aluminous goethite as maghaemite or haematite in some instances.

This final report includes microprobe analyses made at the Central Science Laboratory, University of Tasmania, and explains the considerable solubility of these samples in hot 10% HCl. In general, much of the Cr<sub>2</sub>O<sub>3</sub> is located in aluminous goethite, chamosite and kaolin. As these non-refractory phases may make up over 90% of the sample, their inclusion in a total Cr<sub>2</sub>O<sub>3</sub> analysis severely over-estimates the amount of refractory sand or wash available.

The size range of chromites in MA1 and MA2 fractions observed optically lies between 20 and 400µm but the mean (mode) would be less than 150µm, in contrast to the chromite in the overlying sand horizons.

*Description of individual samples (J. Everard)*

Mass and chemical analysis figures are taken from information supplied by the Metallurgical Research Laboratories in Launceston; XRD, probe analyses and optical descriptions (mounted in clove oil or of polished thin sections) were done in Hobart. Electron microprobe analyses are tabulated at the end of the report.

Optical characters of the main components are:

- Goethite - characteristically ranges from orange-red to near opaque in transmitted light, yellow-grey in reflected light, always anisotropic, birefringence generally masked by colour, high positive relief;
- Chamosite - yellow-orange (less common yellow-green) in transmitted light, fibrous microcrystalline nature, low positive relief, colour zoned - grades into
- Kaolinite - colourless to pale yellow in transmitted light, low birefringence, fibrous and inhomogeneous;
- Chromite - opaque and black, even in small grains - the normally characteristic red-brown colour on thin edges is absent in clove oil mounts;
- Magnetite - opaque and black, recognised by movement in a magnetic field when mounted in clove oil;
- Opaline silica - clear, isotropic and refractive index slightly less than clove oil.

792469

*MA1**Mass* 0.2% of sample head*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 21.9%

Sample not supplied

*MA2**Mass* 4.6% of sample*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 20.2%

Sample not supplied

*N**Mass* 37.9% of sample*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 2.9%

Sample not supplied

*SLIME**Mass* 15.7% of sample*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 2.1%

Sample not supplied

792470

*MA1**Mass* 11.4% of sample*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 7.3%*XRD* (Poor) - quartz, goethite, ilmenite (?)*Probe* Nil*Clove Oil*

A fine, rather poorly sorted strongly magnetic brown sand. Modal grain size about 150µm but commonly ranging from 40µm to 400µm, with a little dust. Contains about 15% opaques with magnetic magnetite, mainly as normal sized grains, rather than as dust. Many other grains, however, contain small magnetite inclusions, rendering them magnetic overall. Also present is quartz (10%), in both single crystallographically continuous grains and in usually larger microcrystalline aggregates. The remainder is opaque to orange red goethite (45%) and almost colourless to yellow and yellow-green kaolinite and chamosite (30%). The green colouration in the latter may be due to chrome, or may be due to a chloritic composition. Goethite is mostly cryptocrystalline. There are many composites: goethite often contains opaque, magnetic inclusions; quartz, goethite and chamosite are often found in single grains, but also with magnetite inclusions. There is a small quantity of non-magnetic opaque anhedral, probably chromite or ilmenite.

*Thin section* Nil

792470 (continued)

MA2

Mass 6.3% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 10.5%

XRD Goethite, quartz (poor)

Probe 6 analyses of goethite: FeO : 57-85%; Al<sub>2</sub>O<sub>3</sub> : 5-22%;  
SiO<sub>2</sub> : 0-14%; Cr<sub>2</sub>O<sub>3</sub> : 2-9%

Clove Oil A rather poorly sorted brown sand with only a few magnetic grains. Grain size ranges from 40- 700µm, but is typically 200µm to 400µm, and most are angular to sub-rounded anhedral. The sample contains non-magnetic opaques, probably chromite (6-7%) as angular anhedral. Magnetite comprises only about 1% or less. Quartz comprises about 5%, both as crystallographically continuous and microcrystalline grains, but is difficult to estimate as it tends to be obscured in composites. The remainder is about 50% goethite (almost opaque to orange-red; largely cryptocrystalline) and 35% almost colourless to yellow-orange and yellow-green kaolinite/chamosite. Both these minerals occur as jagged irregular anhedral with a disordered, fibrous microcrystalline structure, with frequent inclusions of each other, quartz and opaques. Overall, the sample has a very dirty appearance under the microscope with many composites, inclusion-ridden grains, and the poor size sorting.

Polished thin section Is consistent with the above description except that there appear to be less opaques (5%) and less quartz (2-3%).

N

Mass 13.3% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 3.2%

XRD Very poor - quartz only detected

Probe Nil

Clove Oil A fine, light brown sand - a mixture of brown material and white quartz. Only traces of magnetic particles. Sorting poor: most grains are between 30 and 300µm, with a little dust, but 80µm is about the mode. Grains are mostly sub-rounded. Contains dominantly quartz (50%), mostly clear, but sometime cloudy with dark inclusions. Quartz occurs mostly as single grains, but sometimes as microcrystalline aggregates. Contains also about 4% non-magnetic opaques, probably chromite. These are typically fairly angular and irregular to rarely rectangular or oblong in shape. There is also about 1% magnetite and ilmenite occurring as grains themselves and as tiny inclusions, chiefly in goethite. The remainder is almost opaque to dark red and orange-red goethite, mostly cryptocrystalline: and pale yellow to yellow-orange (less commonly yellow-green) kaolinite/chamosite in about equal quantities.

Thin section Nil

SLIME

Mass 57.6% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 3.7%

XRD Very poor - nothing distinguishable

Probe Nil

Clove Oil A moderately magnetic light yellow-brown sludge. A very fine substance consisting of perhaps 5-10% quartz and 1-2% opaques, most of which are magnetic, and about 10% visibly crystalline goethite in a cryptocrystalline orange-red groundmass (80%), probably largely goethite with possibly some kaolinite/chamosite.

792471

MA1

Mass 9.4% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 10.5%

XRD Goethite, quartz, possible spinel phase

Probe Nil

Clove Oil A strongly magnetic dark red-brown sand. Poorly sorted, ranging from 1 mm to 50 $\mu$ m with a modal value of about 150 $\mu$ m. Contains about 10% opaques: 6% are magnetite, 4% are non-magnetic and probably chromite. In addition, there is about 2% quartz. The remaining 88% is goethite. Almost all is cryptocrystalline. Only the sand grains themselves are magnetic; the finer dust mostly is not magnetic, so the magnetism probably derives from magnetite inclusions.

Thin section Nil

MA2

Mass 8.2% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 15.5%

XRD Goethite, quartz, possible spinel phase

Probe Nil

Clove Oil A medium grained chocolate-brown sand, moderately magnetic. Poorly sorted, ranging mostly between 30 $\mu$ m and 700 $\mu$ m, with a modal size of 100 to 150 $\mu$ m. Grains are typically sub-rounded anhedral. Contains about 75% mostly cryptocrystalline, almost opaque to orange-red goethite; about half of it is observably grossly magnetic (grains on a slide in clove oil can be moved by moving a magnet beside the slide), the remainder is non-magnetic. There is some opaque, non-magnetic, anhedral to euhedral (oblong to diamond shaped) material, probably chromite (10%). Magnetic opaques (magnetite) account for about 5%. There is about 5% of yellow to yellow-green chamosite and 5% microcrystalline quartz. Very small magnetite inclusions within some of the goethite grains probably account for their magnetism; quartz also often has inclusions of magnetite and chamosite or goethite (orange-red). However, composites are otherwise not common.

N

Mass 3.1% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 8.5%

XRD Goethite, quartz

Probe Nil

Clove Oil A fine weakly magnetic red-brown powder. Grain size 10 $\mu$ m to 100 $\mu$ m, but sorting fair with a modal grain size of 5 $\mu$ m, and only a few > 50 $\mu$ m. Except for the more angular opaques, grains are typically subrounded to rounded. Contains about 80% goethite; of this about 30% is non-magnetic and largely goes

792471 (continued)

to extinction, and 50% is magnetic and mostly cryptocrystalline. In at least the visibly crystalline grains, magnetism is caused apparently by opaque inclusions. (Note that not all the crystalline grains are non-magnetic, and not all the cryptocrystalline grains are magnetic). Other components are magnetite (2%), non-magnetic opaques (probably chromite) (4%), whole quartz grains and microcrystalline quartz (10%), and almost colourless to yellow-orange kaolin/chamosite (4%). The larger grains are generally quartz or goethite. Traces of zircon and opaline quartz are present.

Thin section Nil

SLIME

Mass 77.3% of total

Analysis Cr<sub>2</sub>O<sub>3</sub> = 2.9%

XRD Quartz, goethite

Probe Nil

Clove Oil An extremely fine, relatively strongly magnetic orange-brown powder. Appears to consist of cryptocrystalline goethite (98%) with a little quartz (2%) as grains ranging from 100µm to < 5µm. There is a little (< 1%) crystalline goethite and traces of non-magnetic opaques (chromite?). The slime has tended to harden into pellets on drying. Note that the analytical result of 2.9% Cr<sub>2</sub>O<sub>3</sub> given must closely approximate the chrome content of the goethite in this case.

792472

MAI

Mass 9.8% of total

Analysis Cr<sub>2</sub>O<sub>3</sub> = 14.9%

XRD Goethite, quartz, spinel phase

Probe Nil

Clove Oil A strongly magnetic grey-brown sand, with numerous white speckles. Very poorly sorted, ranging from 40µm to 1 mm (maximum dimension). Mineral proportions are difficult to estimate, but appear to be quartz (30%), goethite (45%) - of which two-thirds is magnetic and almost all apparently cryptocrystalline, magnetite (20%) and opaque non-magnetic chromite (~ 5%). There are also minor amounts of chamosite. Quartz is typically as microcrystalline aggregates, ridden with inclusions of goethite and sometimes anhedral to oblong euhedral opaques. Goethite occurs as subrounded, irregular dark grains. Magnetite and chromite grains range from large to small grains and constitute the bulk of the fine grained portion of the sample. They occur as both anhedral and oblong to diamond shaped euhedra. The low proportion of chromite (~ 5%) implies a high chrome content in goethite and possibly magnetite to make up 14.9% Cr<sub>2</sub>O<sub>3</sub>. Composite chromite-magnetite fragments are relatively common and may assist to explain the discrepancy.

792472 (continued)

MA2

Mass 16.9% of total  
 Analysis  $Cr_2O_3 = 10.8\%$   
 XRD Quartz, goethite  
 Probe Chromite (3 analyses) with  $Cr_2O_3 = 63-67\%$ ; Goethite (5 analyses) with  $FeO = 81-85\%$ ;  $Al_2O_3 = 11-16\%$ ;  $Cr_2O_3 = 0-4\%$ ;  $SiO_2 = 0.8-2.5\%$

Clove Oil A fine light brown powder speckled with white grains. Contains a minor magnetic component. Poorly sorted, with maximum dimension ranging from 1 mm to dust; modal grain size is probably around 300 $\mu m$ . Consists of inclusion-ridden microcrystalline quartz (35%), cryptocrystalline, almost entirely non-magnetic goethite (60%) and opaque non-magnetic chromite (5%). There are only traces of magnetite, as anhedral rather than dust. There is also a little pale orange-yellow kaolin. Composites are common; the above mineral proportions are very approximate due to this and the large size range.

Thin section Contains anhedral of 40 $\mu m$  to 700 $\mu m$  with little dust. Appears to be better sorted than the clove oil mount, with a modal size of 100 $\mu m$  - probably larger grains and composites broke up during preparation. Consists of irregular microcrystalline quartz (20%), often cloudy with inclusions; almost opaque to amber in colour goethite (70%), much of which is crystalline enough to change appearance on rotation under crossed nicols, and subhedral to anhedral opaque chromite (5-10%) and minor kaolin (1-2%). Sizing information from the clove oil mounts is more relevant, whilst mineral proportions from the thin sections are more accurate.

N

Mass 2.3% of sample  
 Analysis  $Cr_2O_3 = 4.1\%$   
 XRD Goethite, quartz  
 Probe Nil

Clove Oil A fine light brown powder consisting of fine red-brown goethite and coarser quartz. Contains quartz (45%), goethite (45%), chamosite (5%) and opaque non-magnetic chromite or ilmenite (5%) plus minor (<<1%) magnetite and traces of opaline quartz (?). Quartz is about half microcrystalline and half in crystallographically continuous grains. Inclusions of goethitic and chamositic material are common. Goethite is mainly non-magnetic; the less opaque grains are visibly crystalline.

SLIME

Mass 64.6% of total sample  
 Analysis  $Cr_2O_3 = 2.1\%$   
 XRD Quartz (strong), goethite  
 Probe Nil

792472 (continued)

*Clove Oil* A light orange-brown, strongly magnetic sludge containing possibly 10% quartz as grains ranging from 100µm to dust, in cryptocrystalline goethite (90%). There are traces of crystalline goethite and possible kaolin.

792473

*MA1*

*Mass* 6.2% of sample  
*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 5.9%; 1.9% sol. in dil. HCl, 3.5% insoluble  
*XRD* Goethite only; weak and diffuse pattern  
*Probe* Chamosite-kaolin (3 analyses) with 4-31% FeO; 2-3% Cr<sub>2</sub>O<sub>3</sub>; goethite (3 analyses) with 6-17% Al<sub>2</sub>O<sub>3</sub>, 3-11% SiO<sub>2</sub>, 1.8-3.7% Cr<sub>2</sub>O<sub>3</sub>.

*Clove Oil* A fairly well sorted magnetic dark brown sand with grain size ranging from 150µm to 1 mm, with little dust, but with most around 400µm. Consists of irregular jagged equidimensional anhedral; non-magnetic, opaque to very dark red (40%); magnetic, opaque to very dark red (40%); non-magnetic, translucent, orange to brown and green-brown, anisotropic and fibrous (20%). However, many grains are composite and in particular the translucent material often contains inclusions of magnetic opaques, which have caused them to appear in this MA1 fraction.

*Thin section* Chamosite-kaolin 54%; goethite ~ 44%; opaques 2-3%. No quartz. The chamosite-kaolin shows a fibrous structure, but is often poorly crystallised. It ranges in colour from colourless to orange-red, depending on the iron content which varies (at least) from 4 to 31%. In particular, the ferruginous varieties are poorly ordered. Kaolin grains are irregular, ragged flakes and frequently zoned, with an orange-red, ferruginous rim grading to an almost colourless core. The goethite is likewise anhedral, disordered and fibrous. Colour ranges from orange-red to very deep red and almost opaque but is always translucent when the condenser is raised at high power. It is anisotropic, with interference colours completely masked, to apparently isotropic in very fine grained material. There is no pleochroism. High iron kaolin and high alumina goethite are both orange-red and difficult to distinguish, microprobe analyses do not suggest a complete compositional gradation. Completely opaque grains are more angular, and subhedral to rarely euhedral. They are probably magnetite or chromite-magnetite composites.

*Summary* Kaolin and ferruginous kaolin (? chamosite) (54%); goethite and aluminous goethite (44%), which is magnetic; opaques (2%). Well sized at around 400µm with composites abundant.

*MA2*

*Mass* 31.9% of sample  
*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 7.0%; 2.3% soluble in dil. HCl, 4.7% of insoluble  
*XRD* Goethite (moderate), chamosite (weak)  
*Probe* Chamosite (one analysis); goethite-diaspore with SiO<sub>2</sub>, Cr<sub>2</sub>O<sub>3</sub> (three analyses)

792473 (continued)

*Clove Oil* A very fine, magnetic brown sand. Sorting fair - modal grain size around 60µm, commonly 20µm to 150µm, with little dust. Many grains rounded or subrounded. About 10% of the sample is magnetic and almost opaque, but on strong illumination most is seen to be very deep red goethite with only about 1% completely opaque (magnetite). There is also about 1% non-magnetic, completely opaque material, probably chromite. The remainder is dark red to orange-red, non-magnetic goethite (50%) and colourless to yellow-green and orange kaolin and chamosite (40%). There is a small amount of colourless, isotropic, low relief (n < balsam) glass or opal (< 1%) and traces of tourmaline. A few grains only are composites; most are kaolin/chamosites or goethites with small inclusions of magnetic opaques.

*Thin section* Mineral proportions generally agree with as above: 2% opaques, the remainder being goethite and kaolin/chamosite in similar amounts, say 54% goethite, 44% kaolin and chamosite. Goethite again ranges from almost opaque to orange-red, with some of the lighter coloured grains displaying distinguishable 2nd order interference colours (greens). A crude, often wavy fibrous structure is often visible, to which extinction is parallel. Other grains appear to have a very fine disordered structure and are almost isotropic. None are pleochroic. Kaolinite is colourless to yellow and orange-yellow as it becomes more chamositic. Its structure is also fibrous to disordered and pseudo-isotropic; many grains show chamositic rims and kaolinitic cores. Grains are irregular and rounded to ragged. Birefringence is low order greys. Opaques are generally small and angular subhedra and anhedral.

*Summary* 54% goethite /diaspore; 44% kaolin/chamosite, 2% chromite, 1% magnetite, traces quantity of glass or opal and tourmaline.

*N*

*Mass* 13.3% of sample

*Analysis* Cr<sub>2</sub>O<sub>3</sub> = 3.2% 1.6% sol. in 10% HCl simmered for 5 hrs; 1.6% insoluble.

*XRD* Goethite, quartz, minor kaolin

*Probe* Nil

*Clove Oil* A very poorly sorted, mostly non-magnetic light brown sand, containing a few magnetic particles. Particles range from 1 mm to dust, with a modal size of about 40µm. Contains about 10% opaques, of which 2-3% are magnetic (magnetite) and 3-7% non-magnetic, probably ilmenite and chromite. Also contains about 10% colourless, isotropic opal or glass and about 3% quartz. The remainder (about 75%) consists of almost opaque to dark red goethite and colourless to yellow-orange kaolinite and chamosite in approximately equal quantities.

*Thin section* Mineral proportions roughly consistent with as above: 10% opaques, 5-10% quartz, 5% opaline material, remainder goethite and kaolin/chamosite, with perhaps a little more kaolin/chamosite. Opaques and opaline material are mostly angular; quartz, goethite and kaolin/chamosite are more rounded.

792473 (continued)

SLIME

Mass 55.2% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 3.4% 3.1% sol. in 10% HCl simmered for 5 hrs;  
0.3% insoluble

XRD Goethite, lesser kaolin, quartz; possible spinel minerals

Probe Nil

Clove Oil An extremely fine, moderately magnetic brown sludge. Appears to consist largely of somewhat magnetic, brown goethite which is almost opaque. Red-brown and anisotropic under strong transmitted light. No extinction because very fine grained. Other possible components are kaolin and quartz (10-20%).

Thin section Appears to consist of 5% quartz, 5% opaques and 10% goethite and chamosite in a very fine red groundmass, probably largely goethite (80%).

792474

MA1

Mass 55.5% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 9.1%

XRD Goethite, probable spinel mineral (magnetite?)

Probe Nil

Clove Oil A fine, strongly magnetic chocolate brown sand. Poorly sorted, commonly ranges from 400µm to magnetite dust of less than 10µm, with 60 - 70µm being typical. Consists chiefly of magnetite and chromite (40%) and goethite (60%). Magnetite occurs chiefly as fine grained opaque dust of less than 20µm, readily aligned in a magnetic field, although a few larger angular grains are present. Goethite is almost opaque to orange-red, but always anisotropic and translucent under strong transmitted light. Grains are typically irregular but rounded, 20µm to 400µm, and intrinsically non-magnetic although many have magnetite inclusions causing overall magnetism. Minor components are quartz (1%) with lesser light yellow to orange chamosite and colourless isotropic low relief opal or glass.

Thin section Nil

MA2

Mass 18.3% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 7.9%

XRD Quartz, goethite

Probe Nil

Clove Oil A fine brown-red powder with a minor magnetic component. Poorly sorted, with grains ranging from 500µm to dust, although most are in the 35 - 70µm range. Contains about 5% magnetite, mostly as dust with a few opaque angular grains of up to 50µm. About 90% is almost opaque to orange-

792474 (continued)

red goethite, always anisotropic and translucent under strong transmitted light. Many grains are cryptocrystalline and do not display extinction. Goethite grains are typically rounded to subrounded; almost all the larger grains are goethite. There are also irregular grains of quartz (5%) often with goethite inclusions, and minor pale-yellow kaolin/chamosite and colourless isotropic opal or glass.

N

Mass 1.0% of total

Analysis Cr<sub>2</sub>O<sub>3</sub> = 3.6%

XRD Quartz, rather weak goethite

Probe Nil

Clove Oil A very fine brown powder, containing numerous larger (to 1 mm) irregular grains of quartz. Weakly magnetic. The majority of the grains are between 20 and 60µm, but there is much dust and grains are up to 200µm in size. Contains magnetite (4-5%), mostly as fine dust of a few µm diameter, with some larger angular grains but mostly < 20µm. Contains dominantly goethite (85%) as almost opaque to orange-red rounded to sub-rounded grains. There is about 10% quartz and minor yellowish kaolin/chamosite and colourless isotropic opal or glass. Quartz is mostly fairly free of inclusions. Much of the goethite is cryptocrystalline (no extinction).

SLIME

Mass 24.4% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 1.6%

XRD Quartz, rather weak goethite

Probe Nil

Clove Oil A very fine, fairly strongly magnetic orange-brown powder. Appears to consist of about 5% quartz (15 - 40µm grain size). Nearly all the remainder (95%) is goethite; extremely fine grained. Like the cryptocrystalline goethite in other fractions, individual particles are probably < 1µm, but the slime dries into friable irregular pellets of all sizes.

792475

MAI

Mass 67.2% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 7.6%

XRD Goethite, possible spinel phase

Probe Nil

Clove Oil A fine, strongly magnetic, chocolate brown sand with a few white speckles. Poorly sorted, ranging from over 500µm to minor dust; 100µm is about the mode. Contains magnetite dust (25%) and anhedral (5%), colourless to pale yellow chamosite-kaolin (10%), and deep-red to almost opaque (cryptocrystalline) goethite (60%). There is a small amount (< 1%) of quartz and opaline silica. Tiny inclusions of magnetite are common in the other minerals.

792475 (continued)

MA2

Mass 5.7% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 6.6%

XRD Goethite, quartz, spinel phase?

Probe Nil

Clove Oil A fine, strongly magnetic, chocolate brown and similar to MA1 but containing more white grains. Poorly sorted, ranging from over 500 μm to abundant dust, with most grains between 50μm and 100μm. Contains magnetite (20%), largely as dust (< 10μm) with a few larger grains; microcrystalline quartz (10%), colourless to pale yellow chamosite-kaolin (10%) and orange-red to almost opaque goethite (50%). Most of the goethite is magnetic, but in at least the more crystalline, translucent orange-red grains, this appears to be due to the presence of tiny opaque inclusions of magnetite. There is a small quantity (1-2%) of opaque non-magnetic chromite, and minor opaline silica.

N

Mass 1.9% of sample

Analyses Cr<sub>2</sub>O<sub>3</sub> = 4.4%

XRD Goethite, spinel phase?

Probe Nil

Clove Oil A fine, strongly magnetic chocolate brown powder. Although there are a few larger goethite and quartz grains of up to 200μm, the great bulk of the sample is under 80μm, ranging down to magnetite dust. Contains quartz (5%) as crystallographically single grains; magnetite (10%), largely as dust with a few normal sized grains, and goethite (80%) of which about three quarters is magnetic and one quarter non-magnetic. About half is visibly crystalline (orange-red), half cryptocrystalline (almost opaque). There are only traces of chromite and a little (< 1%) kaolinite/chamosite.

SLIME

Mass 21.3% of sample

Analysis Cr<sub>2</sub>O<sub>3</sub> = 1.9%

XRD Goethite, spinel phase?

Probe Nil

Clove Oil A very fine, strongly magnetic dull khaki-brown sludge. Consists almost entirely of cryptocrystalline, mostly magnetic goethite, speckled with a little (few %?) more crystalline goethite and quartz, mostly less than 20μm. Khaki colour is possibly due to atypical chemical composition of goethite rather than mineralogical differences.

Microprobe analyses and comments

Analyses were carried out on a Jeol 50A electron microprobe with Edax energy dispersive analytical facility, corrections were made for atomic number, absorption and fluorescence and analyses are reported on an anhydrous basis. All iron is reported as FeO and analyses are recalculated to 100%. The area scanned varied from a few  $\mu\text{m}^2$  to 400  $\mu\text{m}^2$ .

Chrome spinels (all from 792472/MA2)

	2C	2D	2H
Na <sub>2</sub> O	-	0.67*	-
MgO	8.49	12.35	9.12
ΣFeO	16.96	13.26	16.80
MnO	0.32	-	0.25
CaO	0.41	0.46	0.35
Al <sub>2</sub> O <sub>3</sub>	7.22	8.43	9.92
Cr <sub>2</sub> O <sub>3</sub>	66.40	64.53	63.36
TiO <sub>2</sub>	0.20	0.30	0.20
<b>Total</b>	<b>100.00</b>	<b>100.00</b>	<b>100.00</b>
Mg	3.39 )	4.83 )	3.59 )
Fe <sup>II</sup>	3.80 )	2.91 )	3.71 )
Mn	0.07 )	- )	0.06 )
Ca	0.12 )	0.13 )	0.10 )
Al	2.28	2.61	3.09
Cr	14.01	13.39	13.23
Fe <sup>III</sup>	-	-	-
Ti	0.04	0.06	0.04
R <sup>II</sup>	7.39	7.87	7.45
R <sup>III</sup>	16.40	16.06	16.35
(Fe <sup>II</sup> /Fe <sup>II</sup> + Mg)%	52.9	37.6	50.8
(Cr/Cr + Al)%	86.1	83.7	81.1
( $\frac{\text{Cr} + \text{Al} + \text{Ti}}{16} - 1$ )%	2.4	0.4	2.3

\* Na contamination - probable fingerprint

The chromites are compositionally similar to those elsewhere from the district (see Summons *et al.*, 1980). Their main features are the high chrome content, the similar but variable amounts of Fe<sup>II</sup> as against Mg, and the apparent deficiency of divalent cations - resembling in this respect those from the serpentinite at Barnes Hill itself.

Chamosite - kaolinites

Note: The nature of the 'clay minerals' of lighter colour than the goethites is complex. The analyses fit best to a variable interlayer mixture of chamosite and kaolinite. Since these minerals are related structurally (and to the serpentine group) the assignment is reasonable. The position of Cr in the lattices is still under investigation; presumably it replaces one of the trivalent anions in the octahedral layers.

Chamosite - kaolinites (continued)

	792473/MA1			792472/MA2
	1B	2A	2C	1B
Na <sub>2</sub> O	0.74	0.74	-	-
K <sub>2</sub> O	0.86	-	0.60	-
ΣFeO	17.97	30.90	4.19	10.33
Al <sub>2</sub> O <sub>3</sub>	27.30	31.29	38.94	36.60
Cr <sub>2</sub> O <sub>3</sub>	2.40	2.31	2.10	2.84
SiO <sub>2</sub>	50.72	34.76	54.16	50.23
Total	99.99	100.00	100.00	100.00

Goethites (listed in order of increasing Al<sub>2</sub>O<sub>3</sub>)

	792470/MA2	73/MA1	73/MA2	73/MA1	70/MA2	72/MA2	72/MA2	73/MA2
	1D	3C	4D	3A	1F	2B	2A	4A
MgO	1.11	-	-	-	-	-	-	-
ΣFeO	84.33	87.67	85.87	85.92	77.33	83.34	82.73	73.09
Al <sub>2</sub> O <sub>3</sub>	5.93	6.52	8.14	9.37	11.34	11.45	11.73	11.90
Cr <sub>2</sub> O <sub>3</sub>	2.84	1.80	3.54	1.87	4.52	3.19	3.52	3.41
SiO <sub>2</sub>	5.80	4.02	2.46	3.34	6.82	2.03	2.01	11.59
Total	100.01	100.01	100.01	100.00	100.01	100.01	99.99	99.99

	792470/MA2	72/MA2	72/MA2	73/MA2	72/MA2	73/MA1	70/MA2	70/MA2	70/MA2
	1E	2E	2F	4C	2G	3D	1B	1C	1A
MgO	-	-	-	-	-	-	-	-	-
FeO	78.12	84.05	81.90	71.48	81.61	69.57	60.63	57.30	57.58
Al <sub>2</sub> O <sub>3</sub>	14.57	15.10	15.17	15.21	16.08	16.53	18.54	20.88	21.13
Cr <sub>2</sub> O <sub>3</sub>	7.31	-	0.50	4.08	-	3.67	8.58	7.85	7.94
SiO <sub>2</sub>	-	0.86	2.44	9.24	2.31	10.23	12.24	13.97	13.35
Total	100.00	100.00	100.01	100.01	100.00	100.00	99.99	100.00	100.00

Aluminous goethites are a common feature of lateritic profiles (e.g. Greenvale, Qld., Zeissink, 1969). The amount of chromium in solid solution in the lattice is unexpected but unequivocal. The present explanation is that the alumina rich chromian spinels break down more readily than the high chrome spinels under lateritic weathering and the released aluminium and chromium is taken up in solid solution within the goethite (and clay mineral) lattices.

CONCLUSIONS

The poor results from chromite recovery tests on these samples are explained as the result of incorporation of much chromium into goethite and layered silicate phases - chamosite, kaolinite, in the lateritic weathering of the Tertiary section. It is inferred that most of the chromium came from the breakdown of the high alumina chromian spinels described in earlier reports (e.g. Summons et al. 1980) as the high chrome spinels (chromites) are demonstrably stable in the profile - see analyses, this report.

This result may have been anticipated in view of the known Cr content of lateritic ironstones in the area (e.g. Mt Vulcan, 5.90% Cr<sub>2</sub>O<sub>3</sub>) and the consequent difficulties encountered in pig iron production in the 1870s.

While there are many examples in the literature of secondary alteration of chrome ores (e.g. Coolac; Golding and Bayliss, 1968), it is unusual to find as much Cr entering the goethite lattice; it is suggested that high Al<sub>2</sub>O<sub>3</sub> substitution in the upper part of the lateritic profile has facilitated the entry of chrome into the goethite lattice. The occurrence of Cr<sub>2</sub>O<sub>3</sub> in chamosite and other alteration phases of serpentine minerals to the extent of 2-3% is common.

These results give little encouragement to the operators of the refractory sand/wash plant as bulk Cr<sub>2</sub>O<sub>3</sub> analyses will consistently over-estimate the amount of chromite available.

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