MISTRAL MINES N.L.

EXPLORATION LICENCE NO. 1801

MARKS DAM N.T.

REPORT TO N.T. MINES DEPARTMENT

ANNUAL REPORT 1981

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1. SUMMARY

- During 1981 (specifically March to November) Mistral Mines N.L. conducted local and regional mapping of leucogneiss units and associated ultra-mafic bodies, several areas have been located showing a high potential for finding ruby.

- Satisfactory progress has been made in geological mapping and establishing controls of ruby occurrence. This work is incomplete.

- A model has been presented for the structural geology of ultra-mafic bodies.

- 1:25,000 map showing distribution of leucogneiss units and associated ultramafic bodies.

2. INTRODUCTION


Mistral Mines N.L. Report relates to work carried out on the identification and mapping of potential (Ruby) corundum occurrences within E.L. 1801 which were not included in the joint venture/option agreement with C.R.A. Exploration Pty. Ltd.

3. CONCLUSION

Mapping 1:25,000 prepared by R.W. Lawrence show a number of potential areas for ruby occurrence which require detailed investigation.

The major proportion of the area mapped has been recommended for re-application of E.L. 1801.

4. GEOLOGY

Comprehensive accounts of the geology of the Harts Range region have been advanced by Joklik (1954) and B.M.R. and other government bodies. Rocks are considered to be of early to mid Proterozoic age and are represented by an apparent concordance sequence of meta sediments and meta volcanics which have been subjected to metamorphic effects equal to high grade amphibolite to greenschist facies. They appear to consist of a monotonous, repetitive, relatively flat lying sequence but mappings have indicated several periods of folding have been active. A general stratigraphic appreciation of rock types is given below.

Brady Gneiss - muscovite biotite quartz rich gneiss
Irindina Gneiss - mainly garnet-quartz-plagioclase gneiss
                      with minor quartz feldspathic gneiss, amphibolite, garnet-biotite gneiss,
Naringa Calcareous Member - rare silimanite gneiss and hornblende-plagioclase rich (leucogneiss) gneiss. Flaggy biotite quartzite, clac-silimanite gneiss, pale grey quartzite, marble rare garnet biotite gneiss.

Bruna Gneiss - Megacrystite - feldspar granite gneiss, granite gneiss

Of prime importance to Mistral's interest is the leucogneiss or hornblende plagioclase gneiss within the Riddock Amphibolite member as this unit contains the ruby mineralisation. A study of the early mappings indicate the scale of presentation is too great to give meaningful indications of the spread of this unit in the Harts Range region.

More recent, unpublished mapping (1:100,000) By B.M.R. and N.T. government survey indicate possible extents of the leucogneiss to the south and to the north and west of the Mistral mine camp.

The ruby of interest has been found within a plagioclase rich gneiss, herein referred to as the leucogneiss. This unit is considered to be a meta-gabbro-anorthosite. It occurs within the lower part of the Riddock Amphibolite (Joklik, 1955). Within this unit are bodies of meta-ultramafic, which are now composed of amphibolite and chlorite. Leucogneiss in close vicinity to ultramafic has suffered metasmatic alteration. Metamorphic differentiation was important, producing plagioclase rich and amphibole rich phases. Ruby may occur within either phase. Most of the ruby occurred in layers and lenses within the ultramafic itself, with only minor amounts at the outer edge of the ultramafic. The ultramafics themselves have a complex structure. However, a model is herein presented to explain this structure, while making predictions about the distribution of ruby.

It appears that the most significant ruby has resulted from alteration of $F_4$ isoclines of leucogneiss within the ultramafic.

5. **STRUCTURE OF ULTRAMAFIC BODIES**

At first appearance these bodies appear chaotic. However, the relationships can be explained by invoking the effects of two major deformations ($D_1$ and $D_3$).

Apparently, prior to deformation the ultramafic occurred as one slightly disordant sill intruded into the base of the leucogneiss. During the first deformation, which apparently involved extreme flattening, the ultramafic was boudinaged and folded. Isocinal folding brought leucogneiss into contact with ultramafic producing potential sites for ruby formation. These isoclines of leucogneiss are parallel to an early fabric within the ultramafic, this fabric being defined by the preferred shapes of amphibole grains.

Ruby formation could have occurred at any time after the two lithologies were brought into contact. These appear to be a local control on the amount of metasomatic alteration of the leucogneiss isoclines, as corundum is not ubiquitous. This may have been influenced by local variations of fluid movement within the ultramafic body, perhaps during the time of alteration from pyroxenite to amphibolite. With larger volumes of ultramafic surrounding the leucogneiss there may have been more chance of
proceeding far enough to produce ruby.

This model, which explains the layers within the ultramafic as altered isolines of the country-rock leucogneiss, makes some important predictions about the distribution of ruby. A major $F_1$ isocline was recognized in the face exposed at N9340, and has been represented schematically in Figure 1. In this case there is a major dextral isoclinal fold pair. The potential zone for ruby formation is the western part of the Leucogneiss isocline. This potential zone should be linear overall. In fact 80-90% of the ruby produced came from a broadly linear zone between N9325-N9520 (N.Crowley, pers. comm. 1981). In this area ruby was generally massive within an amphibolite host.

The open cut near "the Knoll" (i.e. at N9170, E4950) has been the other site of production. Here, however, the isolines of altered leucogneiss were thinner. (10-20cm). Ruby in this area occurred as thin hexagonal plates within a generally plagioclase rich host. Some isolines have a sinistral vergence indicating the possibility of there having been more than one early flattening event.

The ultramafics may have been further boudinaged during the $D_3$ flattening deformation. The shapes were then greatly modified during the third deformation, which is characterized by dextral assymetrical folds. The tops of the ultramafic boudins were sheared to the east. This third deformation caused the folding of the internal fabric and the $F_1$ isolines. Locally, quartz has been deposited in wedge shaped veins near the $F_3$ hinges. These features are illustrated schematically in Figure 2, which is based on a face south of the knoll.

b. NATURE OF METASOMATIC ALTERATION

The leucogneiss is the starting material for ruby formation. This has changed composition in the vicinity of the ultramafic, resulting in either a plagioclase rich or an amphibolite rich gneiss. At N9190, E4950 there was an excellent example of an laterialized isocline, where the composition varied between these extremes along the length of the isocline.

Ruby may occur within either variety of altered leucogneiss. However, corundum is not always a product of the alteration. Hence, only occasionally metamorphic reaction, a mechanism is required to increase the proportion of alumina, probably to silica.

The plagioclase rich gneiss within the ultramafic has a variable texture with variations of mafic content and irregular distribution of biotite and amphibole. When corundum occurs it is usually in poorly defined layers. Corundum crystals in this host are almost invariant hexagonal plates, often with a white margarite reaction rim.

It appears that the plagioclase in the altered leucogneiss has a higher An content than in the unaltered leucogneiss. This may well reflect a decrease in silica concentration in the rock while at the same time having a relative increase in alumina and calcium. Alumina is unlikely
to have been mobile and calcium appears to have combined with alumina as plagioclase. This however, may depend on the rate of supply of CaO. When CaO is unavailable an excess in $\text{Al}_2\text{O}_3$ may be produced. If this model is correct the alumina in the albite component at plagioclase is the ultramafic reactant, and An is one of the products. Likewise, corundum in the mafic host has probably originated from a decrease in $\text{SiO}_2$ resulting in local excesses of $\text{Al}_2\text{O}_3$.

It is not known at this stage how the ultramafic could have been responsible for a loss of silica in the leucogneiss. The ultramafic probably crystallized initially as a pyroxenite. Alteration to amphibole and chlorite probably would release $\text{SiO}_2$. A release in $\text{SiO}_2$ may have been associated with regional metamorphism. There does appear to be some alteration of the ultramafic in contact with leucogneiss. This is yet to be documented and explained.

Fander (C.M.S. Report 80/10/64) proposed that the chrome, which is believed responsible for the red colour of ruby, has come from the ultramafic. This is reasonable. It is also possible, if the leucogneiss is in fact an igneous gabbro-anorthosite, that it crystallized with enough chrome to colour the ruby.

This model for the origin of the ruby is only preliminary. Further chemical data from whole-rock geochemistry and mineral analyses using the electron microprobe are required.

5. SIGNIFICANCE OF GARNET LEUCOGNEISS

A garnet bearing plagioclase-rich gneiss generally occurs below the ultramafic. However, no ruby has been found within a garnet bearing host, causing the lower margin of the ultramafic to be generally barren. Only one example of white corundum has been discovered. There is no obvious geochemical reason for this.

A possible explanation is that the layer of biotite gneiss separating the leucogneiss from the garnet leucogneiss may have prevented the later from being folded into the ultramafic. Hence there could still be a possibility of ruby occurring if the two lithologies are in contact.

6. EXPLORATION FOR RUBY/RUBY CORUNDUM

On the basis of the model for the origin of the ruby outline above, exploration for ruby corundum should be divided into three main phases:

a. LOCATION OF ANORTHOSITE/GABBRO UNIT

This involved regional mapping. A combination of photointerpretation and ground traverses can successfully locate the unit. (see 1:25,000 map)

An understanding of the sequence of lithologies and the structural geometry are an important part of the mapping. These become invaluable when the area of the E.L. has to be decreased as areas of above and below the horizon of interest can be immediately eliminated. This is of course,
assuming that no similar units occur elsewhere in the stratigraphy. Similar lithologies have been observed higher in the Riddock Amphibolite, but these were not distinguishable on the aerial photographs.

b. LOCATION OF ULTRAMAFIC BODIES

This phase can be easily accomplished once the limits of the leucogneiss units have been determined.

At present, any bodies located during mapping are noted and flagged. These will be a good starting point for further exploration along strike. The bodies usually outcrop or can be inferred from float in non-outcrop area.

c. TESTING OF ULTRAMAFIC BODIES

Due to the structural control on ruby formation, only a small proportion of the ultramafic bodies are likely to contain significant ruby.

FIGURE 1

Schematic diagram illustrating the relationship between potential ruby bearing rocks and early (presumably $F_3$) isoclinal folding. The ultramafic occurs at or near the base of the leucogneiss. The top contact of the ultramafic has been isoclinallly folded resulting in an isocline of leucogneiss within the ultramafic. The boudinaged nose of this isocline is the starting material for ruby formation. The earlier features are folded by open upright $F_5$ folds. At the locality marked (*) the base of the ultramafic appeared to have been found. (Fold axes plunge in a northerly direction. Diagram based on face exposed at N9340. Not to scale).

FIGURE 2

Schematic diagram illustrating the combined effects of $F_3$ and $F_3$ on the shapes of ultramafic boudins. Arrows indicate the sense of $F_3$ shear on the contacts of the boudin. $F_3$ is dextral, plunging to the north. (Based on section at N9170, E4940).
**Figure 1.**

- Ultramafic
- Biotite, garnet schist
- Garnet leucogranite
- Potential ruby-bearing zone
- Isocline of leucogranite
- Small rubies along this contact

**Figure 2.**

- External fabric wraps around ultramafic boudin
- Fabric folded
- Leucogranite
- Ultramafic
- ? Garnet leucogranite
- Quartz development related to $F_3$ axial plane
- Internal fabric within ultramafic boudin
- $F_1$ isocline of leucogranite, now altered.
7. REPORT ON GEOCHEMISTRY

Geochemical analyses have been carried out to investigate two main problems. Firstly, the determination of the origin of various lithologies and secondly the processes involved in ruby formation.

a. ORIGIN OF LITHOLOGIES

Two samples (1 and 2, Table 1) have chemistry consistent with a classic sedimentary origin.

Two samples of calcisilicate were analysed for comparison with leucogneiss, because this is interpreted by other workers as an impure limestone rather than an igneous gabbro anorthosite. It was considered that an igneous unit may have a chemistry distinguishable from a metasedimentary calc silicate. The main difference between these lithologies is the high SiO₂ (70%) content of the calc silicates compared with the plagioclase rich gneisses (50%). Trace elements data are required to reveal any other differences.

Little variation in the mineralogy of the leucogneiss was observed in the field. This mafic content, 10% or less, consisted invariably of hornblende with varying amounts of biotite. The extremes are a hornblende-rich (6) and biotite-rich (7) gneiss. The major chemical element of both is very similar, as one may expect within a homogeneous igneous anorthositic sill.

The garnet leucogneiss (5) has a higher Fe₂O₃ content. Otherwise the chemistry is similar to the other variety of leucogneiss. It is considered that both varieties have a similar origin.

The high Cr and Ni contents of the boudinaged ultramafic layer within the leucogneiss confirms an igneous origin rather than one derived from chloritic sediments. (Table 1, 10-14)

There are two populations resolvable, within the ultramafic lithologies, from the chemistry. This corresponds to differences recognisable in hand specimen and thin section. The chlorite-rich variety has a relatively high Al₂O₃ (14-15%) high loss on ignition (4-5%) and low SiO₂ (43-35%). In comparison, the amphibole-rich variety has a low Al₂O₃ (2-3%), low loss on ignition (1-2%) and high SiO₂ (54-55%). These different compositions may have resulted from variation in lateration of the original ultramafic, which was probably a pyroxenite.

b. ALTERATION OF LEUCOGENEISS

The leucogneiss in close vicinity to ultramafic has suffered metasomatic alteration. During this alteration metamorphic differentiation was important, producing plagioclase metamorphic and amphibole rich phases. This alteration involved a loss of SiO₂, causing a relative increase in Al₂O₃ which occasionally reached an excess, possibly due to a slower rate of supply of CaO. This same process was invoked for both leucocratic and mafic phases which both act as hosts to ruby.
A specimen of plagioclase rich gneiss (8) was analysed from a layer which contains some ruby. This sample lacked ruby and was considered to represent a lower degree of alteration of leucogneiss. This is shown to be very similar to unaltered leucogneiss (6.7) except for the lower Fe₂O₃ and MgO content. It does not show the expected decrease in SiO₂, yet does have a higher Al₂O₃ content. Hence, there appears to have been more involved than just a simple loss of SiO₂, as proposed previously (see September Report). Of course, samples of plagioclase gneiss containing ruby need to be analysed before any further conclusions can be drawn.

One sample of mafic gneiss containing ruby was analysed (9). This appears to represent the highest degree of alteration of leucogneiss. Significant changes in major chemical elements are a decrease in Si and Ca, and an increase in Al, Mg, Fe, Cr and Ni. The elements introduced, with the exception of Al, are approaching the concentration within the ultramafic lithologies. Al is much more abundant in the altered leucogneiss than in ultramafics, suggesting that this has in fact been immobile during alteration.

A number of trace elements will be analysed in the samples already prepared. Elements to be studied include Rb, Sr, Y, Ga, V, Zr, Nb, and Nd.

A number of samples of altered leucogneiss, with and without ruby, will of course need to be analysed to gain a more complete understanding of the chemical processes involved in ruby formation.

8. MAP SHOWING THE LEUCOGENEISS UNITS AND THE ULTRAMAFICS MARKED SCALE 1:25,000

Although numerous ultramafics have been marked on this map it was not within the scope of the mapping exercise to locate all of the ultramafics in the area. Rather, these should be used as a starting point in the search for other ultramafic bodies along strike. Those with the most potential have been numbered on the enclosed map. The following comments refer to these numbered localities.

1. No F₂₁ folding is obvious. However, due to its size it may have some ruby within it. (Accessible).

2. Two horizons mapped may be related by F₂₁. Where these meet may be the edge of a potential ruby zone. This zone may be just west of the outcropping ultramafic (assuming F₂₁ has dextral vergence). This is an important locality. (Easy access)

3. The non outcrop area rimmed by ultramafic may overlie weathered ultramafic. This is within the F₂₂ zone which repeats the sequence. This is worth investigation. (Reasonable access)

4. Large body of ultramafic. Possible F₁ structures here. Should be investigated. (Easy access: low topographic relief)

5. Large ultramafic body. Should be investigated. Low relief (Access)

6. The scatter of small outcrops of ultramafic may be an indication of F₂₁ folding. Hence, this locality is worth investigation.
9. Two levels of ultramafic bodies within a hill slope. Probably related by F\textsubscript{1}. Hence, there is a high potential for finding ruby. Working this deposit will be complicated by the topography which is similar to that within the mineral claims.

10. Numerous crops possibly related by F\textsubscript{1}. This again is an important locality. These bodies are in the valley area. Hence, access will not be too much of a problem. There is a hill area between this locality and the track.

**TABLE 1**

**GEOCHEMICAL RESULTS OBTAINED TO DATE**

All analyses have been carried out using X.R.T. techniques, with the exception of Na\textsubscript{0}, which was measured using flame photometry. Lithologies are as follows:

1. Biotite sillimanite schistose gneiss
2. Felsic metasediment
3. Quartz, diopside calc silicate
4. Quartz, plagioclase, hornblende, garnet calc silicate
5. Garnet leucogneiss
6. Leucogneiss, hornblende bearing variety
7. Leucogneiss, biotite bearing variety
8. Leucocratic plagioclase mica gneiss
9. Mafic gneiss containing massive ruby corundum
10, 11, 14 Ultramafic, chloritic variety
12, 13 Ultramafic, lacking chlorite.

* The Ce values are less than Nd values. This data is therefore suspect.
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|        |        |        |        |        |        |        |        |        |        |        |        |        |       |
| Cr      | 92     | 62     | 127    | 229    | 1024   | 3294   | 5006   | 5611   | 1777   | 5611   | 1777   | 5611   | 1777   |       |
| Ni      | 66     | 35     | 51     | 10     | 418    | 1086   | 1650   | 1777   | 5611   | 1777   | 5611   | 1777   | 5611   |       |
| Zn      | 101    | 36     | 42     | 6      | 82     | 62     | 91     | 41     | 41     | 41     | 41     | 41     | 41     |       |
| Ce      | 26     | 16     | 5      | 7      | 17     | 34     | 12     | 172    | 172    | 172    | 172    | 172    | 172    |       |
| Nd      | 20     | 10     | 7      | 5      | 0      | 7      | 17     | 664    | 664    | 664    | 664    | 664    | 664    |       |
| La      | 161    | 118    | 134    | 110    | 173    | 34     | 12     | 172    | 172    | 172    | 172    | 172    | 172    |       |
| Sc      | 33.9   | 16.5   | 22.2   | 4      | 5.5    | 17.1   | 11.0   | 12.3   | 12.3   | 12.3   | 12.3   | 12.3   | 12.3   |       |
| Ti      | 7/175  | 2411   | 1815   | 358    | 370    | 985    | 970    | 664    | 664    | 664    | 664    | 664    | 664    |       |
9. SAMPLES TESTED

Sample A - Float from No. 4 Cut
A zoned enlave consisting of felspar - chlorite - amphibole corundum.

This is an unusual sample, an important one when considering that McColl has reported that large masses of ruby corundum were associated with masses of tourmaline. Essentially this sample was a zoned inclusion (the sample has now been destroyed in further examination) consisting of three well defined bands.

The outer zone consisted of idoblastic tourmaline porphyroblasts, porphyroblasts calcite, and masses of fine to medium grained tourmaline and feldspar grains resembling a sieve texture.

The middle zone consisted of fine grained feldspar and minor fine grained chlorite. The core of the enlave consists mainly of feldspar with thin layers of lepidoblastic chlorite, minor scattered biotite and quartz, and green amphibole rich regions with disseminated idoblastic ruby corundum porphyroblasts which have frequently been wholly or partially altered to diaspore.

This sample was either a leuco-gneiss xenolith which reacted with the ultramafic magma forming corundum from a desilication reaction and subsequently altered by hydrothermal metamorphism or an inclusion produced by folding and plastic deformation which has been subsequently altered.

Evidence for hydrothermal metamorphism as opposed to peneumatolysis is based on boron metasomatism; alteration of corundum to diaspore by the reaction $2(Al_2O_3) + 2(H_2O)$ to $2(HAlO_2) + 2OH$ recrystallisation of feldspar in the middle zones and the development of locally coarse green amphibole.

Sample B

Several samples of leucogneiss plagioclase - amphibole - chlorite - corundum granulite float.

This rock is easily recognised by its white green appearance, higher specific gravity, lower degree of weathering and not so prominent foliation when compared to the leucogneiss. With the exception of tourmaline, all the mafic minerals are green or bronze in colour. These samples consist of granulose calcic felspar with lepidoblastic chlorite and bronze mica (not positively identified), and nematoblastic dark green amphibole. Chlorite and a phibole occurs as thin layers in the granulose feldspar. The colour of the corundum varies between pale pink and ruby red; the latter colour being comparatively rare. With rare exception, the corundums occur as hexagonal plates, usually very thin, not more than two or three millimeters thick.

The orientation of 36 corundums relative to the foliation was
recorded. Sixteen corundums lay in the plane of foliation, twelve were at a low angle to the foliation, and eight were approximately normal to the plane of foliation. Accordingly it may only be fortuitous that crystallisation of the corundums appears to have been controlled by the foliation.

Sample C

Leuco-gneiss from contact with ultramafic pod. This rock is relatively altered, and parts easily along the foliation. Feldspars are partially altered to clay minerals, and secondary chlorite and green amphibole are orientated in the plane of foliation. The feldspars are fine grained and exhibit granulose texture. Carbonate is present, and is mainly restricted to the planes of foliation. Although the contact between the two rock types is sharp, there has been considerable movement of fluids between the two. No ruby corundums were found along this contact.

Sample D

Ultramafic and leuco-granulite from the mixed zone taken from outcrop. Granulose feldspar with minor chlorite, green amphibole, and pale pink corundum between two layers of ultramafic composed of medium to coarse grained nematoblastic green amphibole with fine grained lepidoblastic coronitic biotite. The corundum is partly altered to diaspore. The ultramafic layers are rich in carbonate which occurs in sheets sub-parallel to the $S_1$ foliation.

Sample E

Ultramafic and leuco-granulite from the mixed zone, this sample was float. This sample is a feldspar - chlorite - amphibole - carbonate rock containing rare hexagonal ruby corundum plates. A major feature of this rock is the occurrence of very coarse dark green amphibole laths which are up to 1 cm in length. The amphibole laths and the corundum approximately lie in the plane of foliation. In this specimen the coarse amphiboles form only thin layer on the surface. Elsewhere the amphiboles are the grained. The coarse amphiboles are probably recrystallised earlier amphiboles in response to later metamorphic carbonate appears to have been introduced after the development of the later amphiboles.
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11. LOCATION OF E.L. 1801

Illogwa Creek SF/S3-15 (SEE MAP ATTACHED)
MAP SHOWING DISTRIBUTION OF LEUCOGNEISS UNIT AND ASSOCIATED ULTRAMAFIC BODIES.

Legend:
- Leucogneiss unit: Included are parasitic leucogneiss and mafic lithologies.
- Indication of ultramafic:
  - Large body of ultramafic
  - Earthworks where more work should be done.
  - Earthworks abandoned.

Key:
- 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 locations