A FOLD STUDY OF THE LADY LORETTA AREA, N.W.QUEENSLAND

by

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ERRATUM

Plate 2 : "Interpretted" should read "Interpreted"

"doutful" should read "doubtful"

"existance" should read "existence"

Page :4 3rd line, "which" should read "within"

4 8th line, "work" should read "work"

ABSTRACT

Interest in the Lady Loretta area of N.W. Queensland is centred around the occurrence of stratiform lead-zinc mineralization in Lower Proterozoic rocks belonging to the Paradise Creek Formation. The mineralization is associated with two rock types:

a) a contorted 'bedded' lead-zinc sulphide rock,

b) a transposed barite, chert, pyrite, sphalerite rock,

The host rocks are typically carbonaceous, pyritic and dolomitic pelites and psammopelites of locally variable thickness.

Four (4) groups of folds have been recognized within the area:

F_1 - Caused by local intraformational slumping of the mineralized rocks (to which it is restricted) during diagenesis; responsible for the associated deformations of these rocks; and helps to explain their compositional and thickness variability.

F_2 - Associated with a chlorite zone greenschist facies metamorphic event and a fanned slaty cleavage; responsible for the macroscopic geometry of the area.

F_3 and F_4 - Locally developed as low amplitude folds and warps; associated with a poorly defined axial plane structure.

Silicification and ferrugination, in association with both favourable climatic conditions and mineral assemblages, have been able to both preserve and accentuate the poorly developed structural elements associated with the fold groups above, and has thus enabled their documentation.

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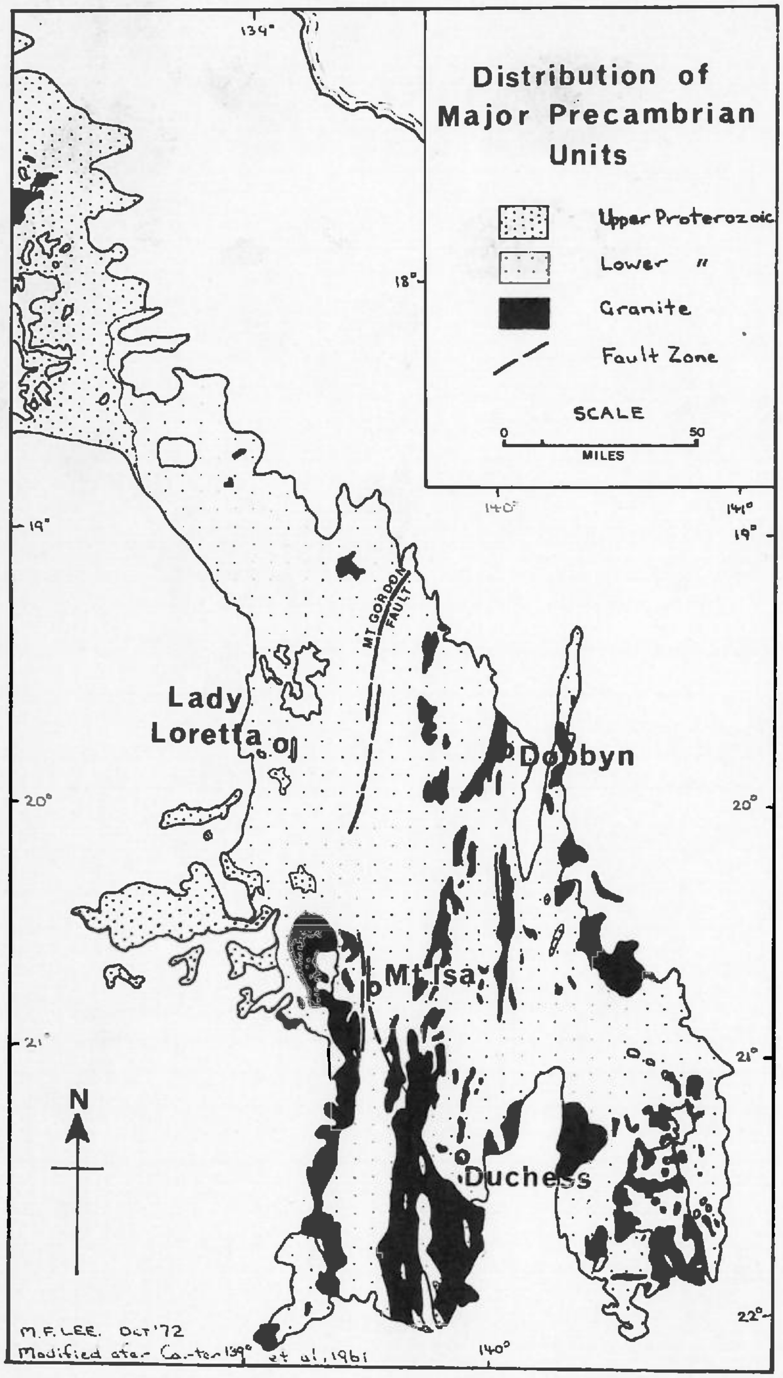

Distribution of Major Precambrian Units
Upper Proterozoic
Lower "
Granite
Fault Zone
SCALE
0
50
MILES
134°
18°
19°
20°
21°
22°
140°
141°
MT GORDON FAULT
Lady Loretta
Dobbyn
Mt Isa
Duchess
N
M.F. LEE. OCT '72
Modified after Carter 139° et al, 1961

FIG 1

INTRODUCTION

The Lady Loretta area is situated 110 Km N.N.W. of Mt. Isa in the Precambrian mineral belt of North-western Queensland; latitude 19°46'S, longitude 139°03'E (fig. 1). Interest in this area was initially centred around the Lady Annie copper mine, 1.5 Km to the west. However, during exploration for more copper mineralization the rocks cored were recognized as being similar to those hosting the lead, zinc and copper mineralization at Mt. Isa. Subsequent inclusion of Pb, Zn and Ag with Cu in a geochemical survey of the immediate area and follow-up drilling led to the discovery of a stratiform lead-zinc deposit in the Lady Loretta area. This mineralization is essentially similar to that occurring in the Mt. Isa, Hilton and McArthur River deposits with the addition of an associated, but discontinuous barite, chert, pyrite, sphalerite rock.

Several difficulties were encountered during the exploration delineation of this mineral deposit:

a) The mineralization is contained within a monotonously homogeneous sequence of pyritic, carbonaceous and dolomitic shales and siltstones with the only distinctive horizon being the mineralization itself. Hence serious subsurface correlation difficulties. The depth of oxidation within the area is of the order of 100m and 200m for the depth of leaching in places. It is also quite possible that there has only been a maximum of 100m of erosion at any one place within the area since Mesozoic times. These factors, combined with the very favourable environment in which ferrugination and silicification can occur, have led to the development of outcrop that is very difficult to interpret in terms of what it was originally when fresh. Hence serious outcrop/subsurface correlation difficulties.

b) Mapping of the area has indicated the existence of at least 4 groups of folds. Only one of these fold groups is thought to be responsible for the macroscopic structure of the area, the others are expressed as minor warps ~~which are~~ but locally important with respect to the shape of the mineralized horizon. Drilling has also shown that the area is complexly faulted. ~~but~~ Unfortunately these faults are difficult to recognize in outcrop, mainly as a result of the extensive ferrugination and silicification that the area has suffered.

c) Drilling also demonstrated the extremely variable nature of the ore horizon in thickness and composition over short distances and its small scale internal folding. This variability can also be observed in outcrop and is possibly of a purely tectonic nature. It is important to understand these variations in order to calculate realistic ore reserves upon which the scale of any subsequent development work is based.

It is the aim of this study to document the fold deformations of the Lady Loretta area, and in particular the relationship between folding and the tectonic variability of the ore horizon. Such a study is seen as being the fundamental prerequisite to all future work on the relationship of this mineralization to its geologic environment.

The author attempted to solve this problem by detailed geological and structural mapping at a scale of 1:480 (1" rep. 40') and by thin and polished section work of both fresh and weathered rocks.

It was hoped that geologic mapping would give:

a) Some idea of the thickness variations of mappable units. This is important as ideal structural analysis relies on a classical layer-cake geological model. Any departure from this model will give rise to a natural distribution of plots of structural elements.

b) Control for fault block reconstruction of the area and the relationship between faulting and the history of folding.

c) Control for subsurface/outcrop correlation. This is necessary for any future exploration and development work.

d) Any relationship between subsurface and outcropping rocks that can be concluded may be helpful in recognizing the surface expression of similar mineralization within the district.

The detailed structural mapping of the area was hoped to:

a) Furnish data capable of either proving or suggesting the validity of the field observed relationships between the 4 groups of folds.

b) Define the characteristics of each fold group.

The ultimate result of this work was hoped to be a three dimensional model of the ore horizon, ~~which~~ within the area mapped, and to illustrate the ways in which folding has caused variability in the ore horizon. Such a model would be by necessity, ideal, but helpful as a visual aid to understanding the ore horizon.

The polished and thin section ~~wek~~ work constituted a necessary back-up study of:

a) the mineralogy of the rocks being studied,

Control of this sort is necessary before attempting subsurface/outcrop correlation.

b) the metamorphic grade of the area and its development, in relation to folding,

c) the structural elements and the relationship between ~~what defines them in fresh rock and what is actually measured on surface outcrops.~~ their fresh rock and surface expressions

Work of this nature helps to characterize the fold groups.

GEOLOGICAL SETTING

The Precambrian mineral belt of N.W. Queensland is bounded to the east and south by overlying Mesozoic sediments belonging to the Great Artesian Basin and to the west by the flat lying Camooweal Dolomite of Cambrian age (?). The regional geology of this area is summarized below, after Carter, Brooks and Walker (1961), and with reference to fig. 1.

The area is thought to have been divided meridianally during the early Lower Proterozoic into two separate eastern and western geosynclinal areas by a north-south trending tectonic welt, passing through Dobbyn and Dajarra. The Lady Loretta area lies within the limits of the western geosyncline. Sedimentation is thought to have occurred continuously in this geosyncline throughout the Lower Proterozoic, at the end of which there was an orogeny with associated folding, faulting, metamorphism and granitic intrusions. The folding west of the Mt. Gordon Fault zone was ~~observed to be~~ dominated by dome and basin structures compared with the general north to N.N.E. fold trends in the remainder of the mineral belt. Wilson (1972) has shown that the area immediately west of Mt. Isa was subjected to a variable grade of regional metamorphism, (chlorite zone to sillimanite zone) during this orogeny. Carter, Brooks and Walker (1961) suggest that the grade of metamorphism decreases northward. The Lower Proterozoic sediments were unconformably overlain by Upper Proterozoic sediments in the western geosyncline. These sediments also exhibit a dome and basin style of fold deformation with the dominant axis striking approximately east-west. They are also referred to as being "practically unmetamorphosed." Brown, Campbell and Crook (1968) have grouped both the Upper and Lower Proterozoic sediments of the Mt Isa Geosyncline as referred to by Carter, Brooks and Walker (1961), ~~of the Mt. Isa Geosyncline~~, into the Carpentarian System. Thin veneers of phosphatic Cambrian and conglomeratic Mesozoic sediments also occur sporadically throughout the mineral field. Faulting is very common and is thought to be of all ages with some of the larger 'basement' fault movements being ~~pre~~contemporaneous with sedimentation (e.g. Mt. Gordon Fault, see figure 1).

The local geological setting of the Lady Loretta area (latitude 19°46'S, longitude 139°03'E) can be appreciated with reference to the Camooweal 4-mile geology sheet (plate 4 of Carter, Brooks and Walker (1961)).

The three outcropping fault blocks of the Myally Beds to the north are thought to represent a fault controlled 'basement' high. The Lady Loretta area lies immediately to the south of the most south-eastern block. An unmapped but major fault, the Carlton Fault, strikes just south of the Lady Annie Mine and the southern tip of the Myally Beds outcrop. It truncates a northerly plunging syncline and in doing so forms the north-western boundary of the Lady Loretta area. Within the area mapped, the stratigraphic displacement associated with this fault is of the order of 2,000 m. The eastern boundary of the Lady Loretta area is the contact between the Cambrian and Precambrian strata, which is also possibly fault controlled. Then the only sediments outcropping in the area of interest are these belonging to the Paradise Creek Formation.

According to Carter, Brooks and Walker (1961, page 105), the Paradise Creek Formation is a sequence of thinly bedded, impure dolomites, siltstones and sandstones which commonly show gradual variations in lithofacies along strike. The formation is characterized by numerous beds of stromatolites which presumably have no stratigraphic value as marker horizons and only serve to indicate that shallow water conditions prevailed during their development.

The above comments are generally true for the Paradise Creek Formation in the general Lady Loretta area. However, the mineralized Lady Loretta rocks are characteristically pyritic and carbonaceous. The suggested thickness for the formation is between 3,000 m and 5,000 m. It is conformable with the Gunpowder Formation below and unconformably overlain by the Upper Proterozoic Pilpah Sandstone, flat-lying Cambrian and Mesozoic strata above. Then considering the fact that the mineralized rocks of the Lady Loretta area occupy the core of a large synclinal structure, it is quite probable that this mineralized horizon occupies a stratigraphic position close to the top of the Paradise Creek Formation and that the maximum thickness of sediment that covered the deposit at any one time was of the order of 2,000 m.

STRATIGRAPHY (Subsurface)

There are two ~~basic~~ main rock types represented within the Lady Loretta area;

a) those composed mainly of sulphides and referred to as mineralized rocks,

b) those rocks surrounding these sulphides and referred to as host rocks.

The host rocks are a sequence of thinly laminated to thin bedded pyritic, carbonaceous, dolomitic sediments with varying amounts of detrital material ranging in grain size from fine sand (0.1 mm diam) to medium silt (0.02 mm diam) and with varying amounts of mica, mainly muscovite. It is thought that the mica in the rocks is of a metamorphic origin and it is then assumed that the amount present is a direct measure of the amount of clay minerals that were originally present in the sediment. ~~Then~~ The terms "pelites" and "psammopelites" should be used to describe, the different Lady Loretta lithologies instead of "shales" and "siltstones" (Wilson, 1972, page 40). However, the latter terms are of more practical value and are therefore used here.

The detrital material is dominently quartz, with local concentrations of feldspars (especially K-feldspar) and chert. The composition of the dolomite present is thought to vary between that of true dolomite ($CaMg\ (CO_3)_2$) and ankerite ($Ca(Mg_{0.67}Fe_{0.33})(CO_3)_2$). It should therefore be referred to as ferroan dolomite. Also, considering the low grade of metamorphism that these rocks have undergone and after Landis (1971), the carbonaceous material ~~associated with this sequence of rocks~~ is likely to be a disordered variety of graphite (Fig.12). The main micas present are muscovite and paragonite with minor amounts of chlorite (Fig.13). Their development is controlled by the local composition of the rock (Fig 15).

The main lithologies found within the host rocks of the Lady Loretta area are described in appendix A. The slides described and the rock types represented in them are listed below:

394/01 : laminated dolomitic carbonaceous siltstone, 'bedded' pyrite,(Fig. 14) tuffites

394/02P : poorly bedded dolomitic shale, dolomitic carbonaceous siltstone

394/04 : pyritic dolomite

394/06N : carbonaceous dolomitic sandstone

394/10 : poorly bedded dolomitic micaceous siltstone (Fig. 12, 13)

394/11 : calcareous arkose

394/13 : rusted micaceous carbonaceous sandstone

394/17N : pyritic argillaceous dolomite, (Fig.16)
carbonaceous siltstone

394/18N : laminated carbonaceous dolomite (Fig.15)

394/19N : silty dolomitic carbonaceous shale,
slump material

Almost all the combinations of pyrite, carbonaceous material, dolomite, shale (mica) and detrital material to form a sediment are represented. Many of the lithologies listed above can be observed anywhere within the host rock sequence and associated with any other. Diamond drilling within the area has indicated that gradations from one lithology to another are common and can occur over short distances (e.g. 150 m). 'Bedded' pyrite and carbonaceous dolomitic siltstones commonly show this relationship. The tuffites present in the sequence are similar to those associated with the Mt. Isa and McArthur River lead-zinc-silver deposits (Croxford, 1964 and Croxford and Jephcott, 1972), excepting that no shards were observed in the <u>one</u> specimen examined microscopically, nor are they always continuous in their development. The calcareous arkose (394/11), referred to above, is rich in chert and K-feldspar (adularia?) detrital grains and occurs immediately above a tuffite bed. This is a common association. Sedimentation of a cyclic nature is also well developed within the host rocks. The ideal cycle consists of a basal sandstone or siltstone, commonly with slump material of any of the locally represented lithologies (394/19N), grading to a siltstone or shale and becoming more dolomitic and carbonaceous to a bed of 'bedded' pyrite at the top of the cycle.

Due to the homogeneity of the host rocks it was necessary to try and subdivide them on the basis of sedimentary structures and or the proportion of a particular lithology, such as 'bedded' pyrite. The sequence subdivision used is given below and defined and described in appendix B:

Upper Carbonaceous Shale

Cyclic Beds

Lower Carbonaceous Shale

Mineralized Rock

Lower Siltstone

The mineralized rocks are basically a sequence of banded dolomitic carbonaceous sulphide rocks with an associated stratiform horizon of a barite, chert, pyrite, sphalerite rock. The banding of the sulphides is parallel to the bedding of associated detrital sediments and therefore the sulphides are referred to as being 'bedded'. Pyrite, sphalerite and galena are the main sulphides present with minor amounts of chalcopyrite, arsenopyrite and hematite. The barite, chert, pyrite, sphalerite rock is referred to as being stratiform as it occupies a definite stratigraphic horizon. It is layered and it will be shown later that this layering is macroscopically parallel to bedding. This material is thought of as being originally deposited as a sediment, but tectonically modified since.

The sulphides present are typically fine grained (0.001 mm to 0.01 mm diam.) and monomineralic grain aggregates are commonly only an order of magnitude larger (Fig. 14). The sulphide/sulphide grain boundary relationships suggest an attainment of equilibrium between the sulphides. Carbonaceous material is invariably associated with the 'bedded' sulphides.

There are three main types of rock making up the Mineralized Rock Unit:

'Bedded' Lead-Zinc Mineralization (394/24X, 394/27X 394/34)

Barite-Chert Rock (394/08, 394/25)

Massive 'Bedded' Pyrite (394/29, 394/01)

These lithologies are defined and described in appendix C. The references apply to thin section, polished-thin section and polished section descriptions of typical examples of these rocks in appendix A.

As evidence supporting the sedimentary or at least early diagenetic deposition of the mineralization, a limited number of slumps of both detrital sediment and 'bedded' mineralization have been observed within the lead-zinc mineralization. The most common detrital sediments associated with the 'bedded' mineralization are laminated micaceous carbonaceous dolomitic siltstones (394/13, 394/01) and poorly bedded argillaceous dolomites (394/17). Cross-crystallized quartz (394/24 and Fig. 17) is characteristic of both the lead-zinc mineralization and to a minor extent the 'bedded' pyrite (Fig.14). Small scale kinking (wavelength of about 5 mm) is commonly associated with the development of cross-crystallized quartz. Boudinaging of sulphide layers has also occurred, especially in 'bedded' pyrite and the more massive developments of lead-zinc mineralization where there is also associated galena and minor sphalerite veining. The barite-chert rock is a homogeneous barite, chert, pyrite, sphalerite rock with minor amounts of galena and occasional developments of fine grained massive pyrite and chert lenses. 'Bedded' pyrite forms a base to the Mineralized Rock unit. It also occurs as local concentrations within the host rocks and is generally associated with the 'bedded' lead-zinc mineralization, around which it is thought to form a halo (c.f. Mt. Isa; Bennett, 1965).

Excepting for the barite-chert rock and the absence of framboidal pyrite and 'silica-dolomite' copper mineralization, the mineralization and host rocks of the Lady Loretta area are very similar to the Urquhart Shale Formation of the Mt. Isa Group (Bennett, 1965) and the HYC Member of the McArthur River Group (Croxford and Jephcott, 1972) and the lead-zinc mineralization associated with these rocks.

All the rock units of the Lady Loretta area show significant variations in thickness throughout the area mapped, especially the mineralized rocks. For example, in one instance of two barite-chert rock intersections approximately 100 m apart, this lithology was about 30 m thicker in one than the other.

These variations may be due to any number of the following reasons:

a) Inaccuracy in defining the contacts of the units. The thickness of the Mineralized Rock unit is highly variable from about 20 m to 110 m. Similar variations also occur in the Cyclic Beds unit (30 m to 90 m) and Lower Carbonaceous Shale unit (20 m to 80 m). It is estimated that inaccuracies in defining the contacts of these units could be as great as 30 m, in any one unit. But corrections of this magnitude do not account for all the thickness variability in these units.

b) Thickness variation due to folding. Assuming average limb dips of 45° for a fold of class 1C (i.e. shear fold) and for thicknesses measured orthogonal to bedding, a bed 35 m thick on the limb will be 50 m thick in the axis of the fold (Ramsay, 1967, chapter 7). It will be shown later that the model used above is applicable to the macroscopic structure of the area mapped. Then the thickness variations of the units mapped cannot be fully explained as being due to the folding responsible for the macroscopic geometry of the area. However, earlier or later phases of fold deformation <u>may</u> be responsible.

The host rocks and massive 'bedded' pyrite only rarely show drag folds. In contrast, the 'bedded' lead-zinc mineralization is typically highly contorted by small scale folding (394/27X). The barite-chert rock layering, although parallel to bedding, is of a tectonic origin. Then it is not known to what extent fold deformation has been responsible for the thickness variations in these two lithologies.

e) Different thicknesses of sediment originally deposited.
The variables above seem unable to account for all the variability in the unit thicknesses. Then it seems reasonable to suggest that local variations in the thickness of the sediment original deposited (lenticular model of sedimentation) may be partly responsible. If so, the rocks formed will not have parallel bedding planes and any structural elements measured on them will show naturally induced variations in orientation. Unfortunately, without any details of such a non-classical layer-cake geological model, no realistic estimates can be made as to what the effects will be on the different structural elements.

Diamond drilling has tentatively illustrated that there is a general tendancy for the rock units to thicken to the north. The author has no data to support this statement.

Then the geometric model of the sequence from a purely sedimentological point of view is one of:

a) bedding diverging to the north due to a general thickening of the sediments in this direction,

b) variably orientated bedding due to different thicknesses of sediment deposited locally (lenticular model of sedimentation).

c) the 'bedded' lead-zinc mineralization and the barite-chert rock of the Mineralized Rock unit are especially variable in thickness and development and this <u>may</u> be largely due to fold deformations other than that responsible for the macroscopic geometry of the area.

It will be shown below that the geometric model, as outlined above, is partly confirmed by the detailed mapping carried out within the area.

STRATIGRAPHY (Outcrop)

Please refer to Plate 1. Exploration diamond drilling, within the area mapped, indicated that the structure of the area was complex and that the sediments vary in both composition and thickness. It is also difficult to accurately correlate sub-surface rocks with the generally siliceous and or ferruginous outcropping lithologies. Then the idea behind the production of the Geological Outcrop Fact Map was to map the outcropping rocks on the basis of their surface lithology and with no regard for stratigraphic units. Such a map can then be used as a control for interpretive work. The lithologies mapped are defined and described in appendix D.

Of the lithologies mapped, the Banded Limonitic Shales and Siltstones and the Sandstone around 5700N 1400W, do not belong to the rocks hosting the lead-zinc mineralization. The outcrops mapped as Hematite, Barite-Chert Rock (394/08, Figs. 2, 3, 4), Silicified Breccia and Mineralized Rock (394/36) are thought to be the oxidized equivalents of the Mineralized Rock unit. Lenses and tight isoclinal folds of chert (394/08, Fig 2) in a layered, grey, fetid fine-grained barite plus quartz (chert?) matrix characterize the Barite-Chert Rock. Hematite is commonly found as a capping to the Barite-Chert Rock, but can also be the oxidized equivalent of lead-zinc mineralization as well as being associated with the surface expressions of faults and massive 'bedded' pyrite. The outcrops mapped as Mineralized Rock are the completely silicified equivalents of lead-zinc mineralization, identified by the presence of cross-crystallized quartz and associated kinking. The Silicified

Breccia is thought to be a brecciated Barite-Chert Rock. All these lithologies are either highly siliceous or ferruginous.

There is a tendancy for the sediments on either side of the outcropping equivalents of the Mineralized Rock unit to be highly silicified. The Siliceous Shales and Siltstones (Fig. 8, 10), Siliceous Honeycombed Rock (Fig 9) and Chert are all thought of as detrital sediments that have been silicified to varying degrees during weathering. The honeycombing in the Siliceous Honeycombed Rock is thought to have been caused by the oxidation of secondary pyrite crystals and aggregates. No primary textures have been observed that could explain this honeycombing. In contrast to the primary chert associated with the Barite-Chert Rock, the Chert mapped is of a secondary origin.

The Upper (Figs. 7, 8, 11) and Lower (394/37) Limonitic Shales and Siltstones are lithologically very similar in outcrop. However, the latter is siltier and contains cross-beds and load casts. These rocks are correlated with those hosting the mineralization. The subsurface subdivision of the sequence is not recognizable in outcrop. However, the lithologies mapped as Massive Siliceous Limonite and Cellular Limonite (which occur within the Upper and Lower Limonitic Shales and Siltstones) are thought to be the outcropping equivalents of beds of almost massive 'bedded' pyrite and are therefore correlatable. The Sandstone mapped around 6100N 1400W is only a coarser grained lens of detrital material within the Lower Limonitic Shales and Siltstones.

The outcrop/subsurface correlations suggested above support the ideas expressed by Blanchard (1968, chapters: 4, 6) on the transportation and precipitation of silica and iron in the vicinity of massive sulphide rocks. The acid produced from the oxidizing pyrite of the Mineralized Rock unit has several effects on the country rock surrounding it:

a) The carbonates present will attempt to neutralize the acid produced. In the Lady Loretta area the depth of leaching can be twice as deep as the depth of oxidation, implying that there is insufficient carbonate present to neutralize all the acid produced.

b) The high acidity ~~and~~ along with the carbonaceous material help to dissolve silica and keep the iron in a soluble form. Then local neutralization by carbonate will result in the precipitation of silica and the formation of jasper (or chert if there is no iron present). Hence the siliceous nature of the outcropping rocks associated with the exposed Mineralized Rock unit.

c) The acid produced will attack the other sulphides present, with the formation of a soluble? mineral sulphate and the precipitation of iron oxides. In the Lady Loretta area this process appears to have resulted in the oxidation of all the other sulphides in the Mineralized Rock unit and the precipitation of all the iron indigenously to produce clean secondary cherts immediately outside the unit.

d) It is typical of the Upper and Lower Limonitic Shales and Siltstones that the bedding trace is defined by limonite that has replaced carbonaceous material, especially in dolomitic carbonaceous siltstones. This is a very common phenomenon within the Lady Loretta area.

It is very important to understand the principals above, as the kinds of silicification and ferrugination that have occurred in outcropping rocks determines the extent to which structural fabrics are preserved, irrespective of how well the fabric was originally developed in the fresh rock.

The outcrop relationships of some of the lithologies mapped, conform to the geometric model that was developed for the Lady Loretta sequence. A general trend of bedding diverging (increasing in thickness) to the north can not be observed. There are, however, several examples of lenticular developments of sediments:

a) The Cellular Limonite centred around 6200N 500W is discontinuous along strike.

b) The two Cellular Limonite outcrops from 6420N 220W (where they probably converge) to around 7300N 240W (where the top one is discontinuous), diverge to a maximum separation (measured on the surface) of 40 m.

c) The Sandstone mapped around 6100N 1400W grades into the Lower Limonitic Shales and Siltstone lithology to the east. It also becomes thinner in this direction as is shown on the map (plate 1).

Mapping also demonstrated both the compositional and thickness variability of the outcropping equivalents of the Mineralized Rock unit. The eastern limb of the synclinal structure illustrates this best:

a) Small scale folds that are probably associated with the internal deformation of the lead-zinc mineralization occur at 6550W 400W and 7010N 1700W (Plate 2).

b) The continuous outcrop of the Hematite in the east shows both the thickness variability of the Mineralized Rock unit (0-55 m, measured on the surface) and its variability in composition (where it includes the Barite-Chert and Siliceous Breccia to the north-east).

c) Part of this thickness variation is due to <u>lobes</u> on the <u>upper</u> contact of the unit at: 5570N, 560W; 5680N, 500W; 6100N, 360W and 6410N, 300W. Although the outcrop of the lithologies equivalent to the Mineralized Rock unit is discontinuous on the western limb of the syncline, the units variation in thickness and composition is obvious.

METAMORPHISM

Carter et al (1961) believed that the area around Lady Loretta was virtually unmetamorphosed. Whole rock X.R.D. analyses of the specimens 394/06, 394/17, 394/25 and a surface sample of a barite-chert rock (refer to appendix A), showed that the following minerals are present in the Lady Loretta area;

quartz (alpha)
ankerite (ferroan dolomite)
muscovite
paragonite
chlorite
graphite (disordered)
barite
pyrite
sphalerite
galena

and suggested the existance of hydrazinium zinc sulphate, calcium manganese oxide hydrate and other unidentified minerals. Other minerals observed during a petrological study of the rocks and which are not included above are;

hornblende? (detrital)
plagioclase
K-feldspar (probably adularia)
minor Fe, Cu and As sulphide and oxide minerals

Of these minerals, muscovite, paragonite, chlorite, graphite and possibly some of the feldspars are of metamorphic origin. Most of the other minerals have undergone at least some re-crystallization, remobilization and or strain. Then according to Wilson (1972, page 39), the mineral assemblage would be classified as belonging to the chlorite zone of the greenschist facies grade of metamorphism. However, epidote was not found in the one chloritic basic volcanic rock (394/06) analysed.

Landis (1971) studied the increase in atomic order of graphite with an increasing grade of metamorphism. Then for the grade shown above, the graphite in the Lady Loretta area should have a disorder of d_1 or d_{1A}. This implies that the carbonaceous material has the orientation of true fully ordered graphite but with a slightly larger interlayer spacing and that it is also probably intermixed with fully ordered graphite. Hence this material is referred to as "carbonaceous material" and not graphite. The concept of being able to have a series of carbonaceous materials (disordered graphites) that are stable at low temperatures (around 200°C) and which are probably capable of re-distribution at these temperatures (or equivalent pressures) is important, especially with respect to the development of carbonaceous material as an axial plane structure to folds formed at low temperatures and pressures.

The micas and carbonaceous material define both a slaty cleavage and a layering parallel to bedding (Fig 12, 13, 15, 16). The development of the slaty cleavage, the galena and sphalerite veining associated with the lead-zinc mineralization and the equilibrium of the grain boundary relationships between sphalerite and the other sulphides, are all thought to be genetically related to the green-schist facies metamorphic event. Petrological studies of the stratigraphic sequence have indicated the presence of at least two other periods of change in the rocks.

a) The rusting of pyrite in the specimen (394/13), the occurrence of specular hematite in the lead-zinc mineralization (394/34, 394/27) and the alteration of chalcopyrite to chalcocite and hematite imply that oxidizing conditions have existed within fresh rock. This could be a deep weathering phenomenon associated with fault zones.

b) It is thought possible that at least some of the adularia, mica elongated parallel to bedding, 'blebs' and cross-crystallized quartz were grown during diagenesis. The mica and carbonaceous material that define a layering parallel to bedding could have been either detrital, grown diagenetically or developed in association with folding. This problem will be discussed later. The 'blebs' (394/02, 394/10, 394/17 and fig 16) appear to be of a diagenetic origin since bedding passes through them without ~~interpretation~~ interruption and they have locally affected the development of the slaty cleavage. The cross-crystallized quartz grains (394/24, 394/29 and fig 17) are commonly sigmoidal and strained as a result of bedding plane slip during later folding. A unique age of formation of cross-crystallized quartz can not be assigned with confidence.

Figure 2 : 6380N 1220W Barite-Chert Rock (chert fold, F_1)

Chert fold (F_1) in a barite + quartz matrix that has been transposed and which now defines the axial plane structure to the fold (i.e. barite layering, S_1)
This is a true cross-section of the fold.
(North is towards the top right-hand corner)

Figure 3 : 6350N 1150W Barite-Chert Rock (layering trace vs bedding trace)

The trace of the original bedding (S_o) of the Barite-Chert rock is cut by the trace of the barite layering (S_1) or axial plane structure to F_1 folds.
A minimum of transposition has occurred and this is uncommon for the Barite-Chert Rock in general.
The intersection of S_o and S_1 produces a rodding (L_1).
This is a section normal to this rodding.
(North is towards the top right-hand corner).

FIG 3

10 CMS

FIG 2

10 CMS

<u>Figure 4</u> : 5610N 1130W Barite-Chert Rock
(barite layering, S_1)

The chert and quartz rodding (L_1) can be seen on the barite layering (S_1) along with the crenulation of this layering which defines L_2. The L_3 and L_4 lineation orientations are shown but are not as obvious. They are defined by the occasional elongation of quartz aggregates. These fabrics have been accentuated by the differential weathering of the barite from the rock.
This section is parallel to the barite layering (S_1).
(North is towards the right).

<u>Figure 5</u> : 394/25 Barite-Chert Rock (grain elongation)

Barite grain elongation parallel to the layering trace (S_1).
Transmitted light, crossed polars
(X 50)

FIG 4

5 CMS

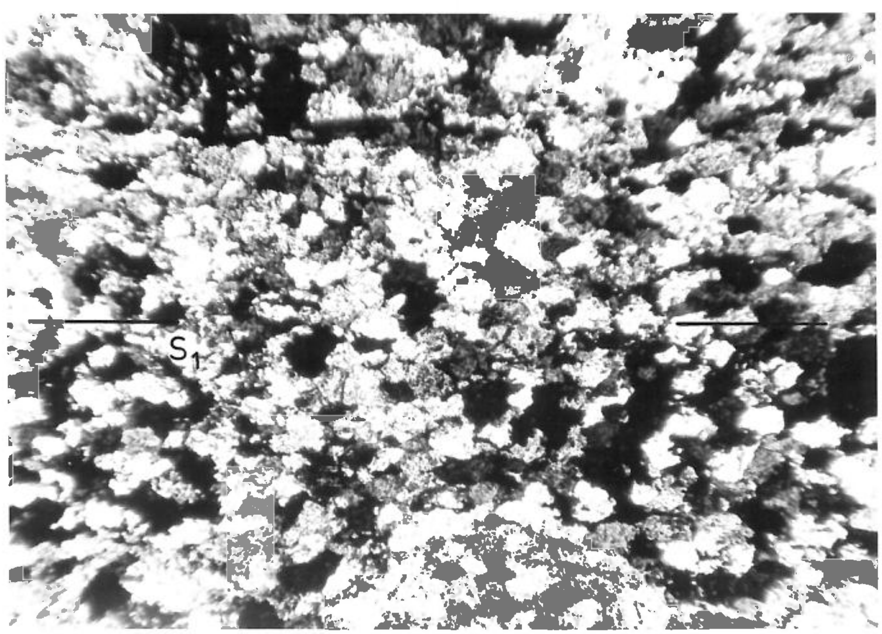


FIG 5 X50

<u>Figure 6</u> : 6630N 490W Silicified Shales and Siltstones (F_4 fold)

Some redistribution of the lineations L_2 and L_3 can be seen as they cross the F_4 fold. Macroscopically both L_2 and L_3 can be shown to be sigmoidally redistributed across this fold.
These lineations <u>appear</u> to be limonite filled joint planes (they are more pervasive than the photograph illustrates).
(North is towards the bottom left-hand corner, as shown by the compass).

<u>Figure 7</u> : 5690N 1080W Upper Limonitic Shales and Siltstones (F_3 fold)

The intersection of bedding (S_o) and the limonitic cleavage (S_2) defines the lineation, L_2. It is well developed and folded by a group 3 fold, F_3, as indicated.
(North is towards the top right-hand corner, the pen is pointing towards 320^o.)

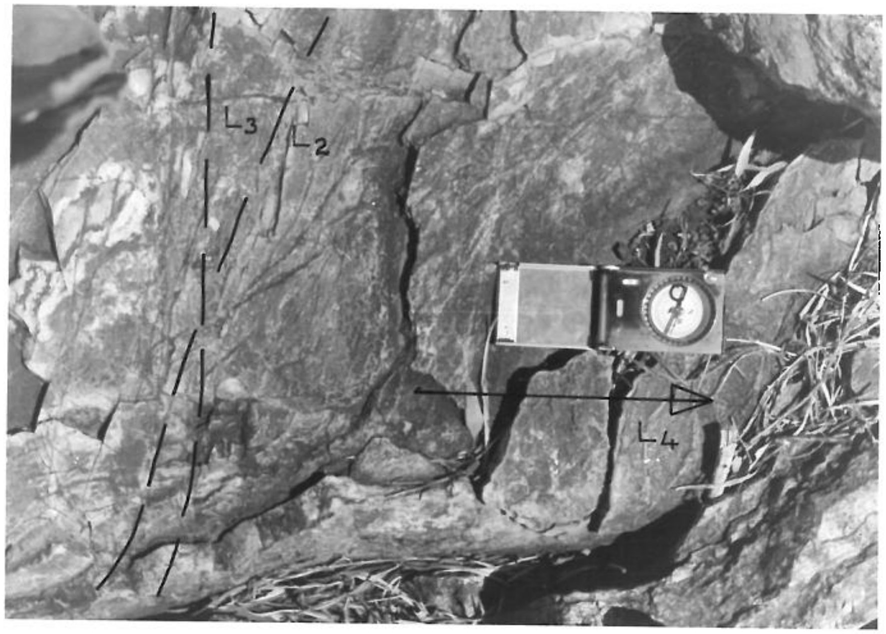


FIG 6

10 CMS

FIG 7

10 CMS

<u>Figure 8</u> : 7290N 780W Upper Limonitic Shales and Siltstones (F_2 fold)

F_2 drag fold on the eastern limb of the syncline. The fanned cleavage (S_2) associated with this group of folds is shown by its intersection with the section cut through the rock (mainly joint planes).
(North is towards the bottom ~~left~~ right-hand corner, the hammer head points towards the north).

<u>Figure 9</u> : 6720N 480W Siliceous Honeycombed Rock (bedded honeycombing)

The honeycombing <u>appears</u> to be bedded, the lithology of the rock type has controlled the development of the honeycombing. No primary textures in the rock can account for the honeycombing and it is therefore thought to be a secondary feature. The holes are commonly filled with limonite (394/35).
(North is towards the bottom left-hand corner).

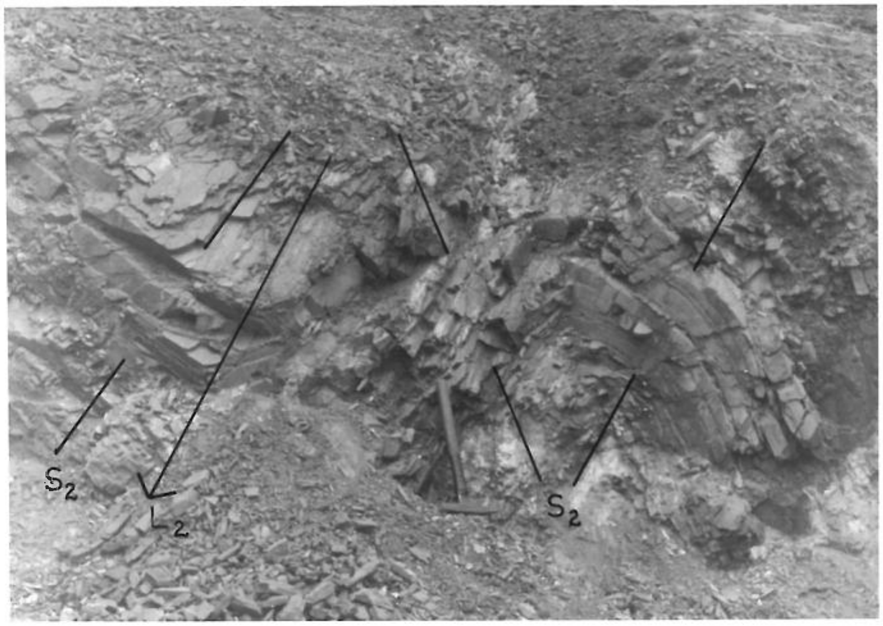


Fig 8

50 Cms

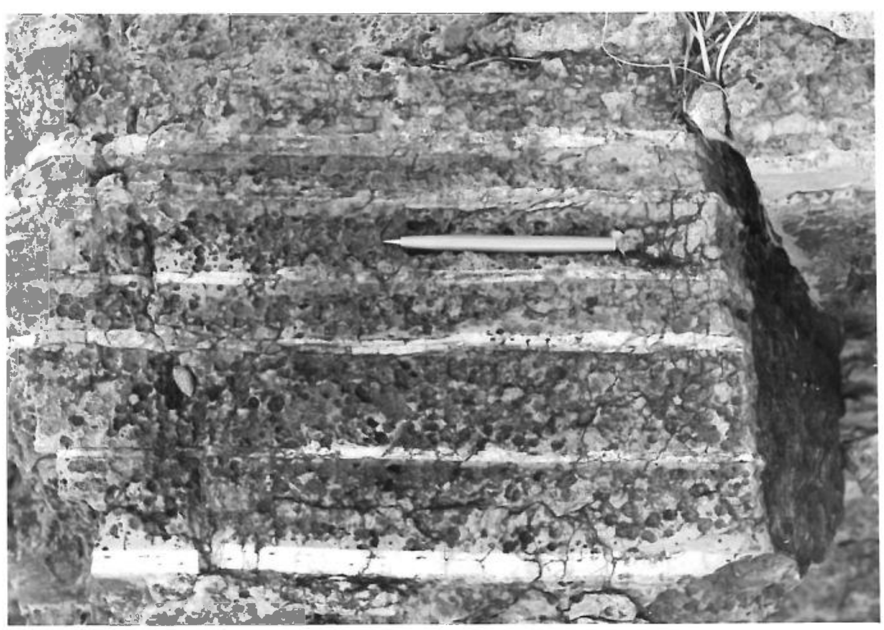


Fig 9

10 Cms

<u>Figure 10</u> : 6640N 510W Silicified Shales and Siltstones (bedding and 2 cleavages)

Bedding (S_o), and two cleavage traces (S_2 and S_3) can be distinguished as a result of accentuation by differential weathering. S_o is defined by a line of holes and S_2 by the elongation of these holes and smaller depressions. Small ridges define the trace of S_3.
The section is normal to bedding. (North is towards the bottom left-hand corner.)

<u>Figure 11</u> : 7240N 840W Upper Limonitic Shales and Siltstones (cleavage, S_2).

The bedding (S_o) trace and cleavage trace (S_2) are shown on a joint face. S_o is defined by different degrees of limonite impregnation around limonitic bands after 'bedded' pyrite and the S_2 trace is defined by a streaking which is thought to be part of a pervasive microstructure. The original microstructure was probably defined by mica (c.f. Fig. 16, 394/17) which has since decomposed with minor inhomogeneous replacement of it by limonite. There is a poorly developed parting parallel to S_2.
This section is approximately perpendicular to both bedding and cleavage (East is towards the left).

Fig 10

5 Cms

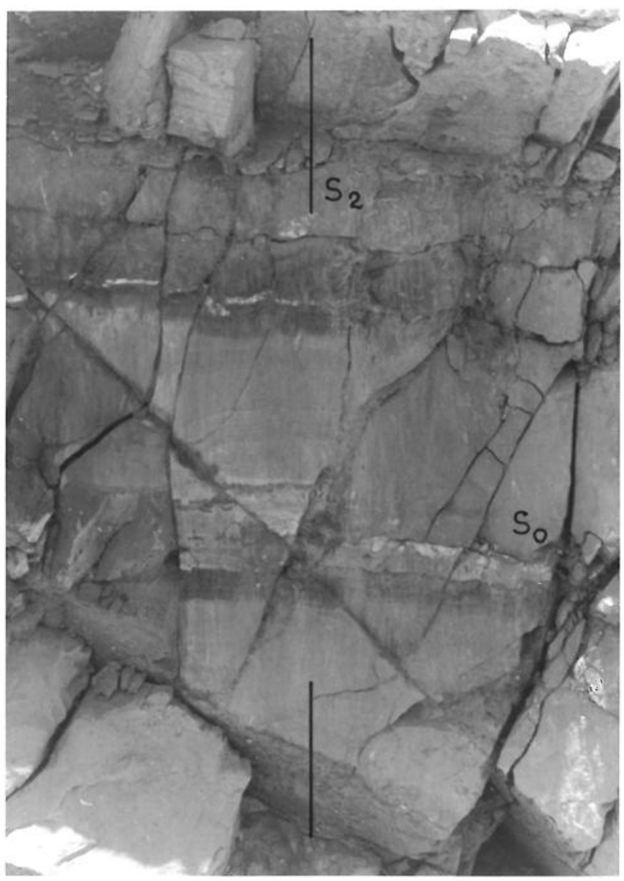


Fig 11

10 Cms

Figure 12 : 394/10 dolomitic micaceous siltstone (carbonaceous material cleavage, S_2, and bedding, S_o)

The carbonaceous material defines both the bedding trace, S_o, (concentrations parallel to S_o) and the cleavage trace, S_2, (wisps of carbonaceous material wrapped around grains and elongated parallel to S_2). The carbonaceous material defining S_2 appears to have been redistributed from that defining bedding. Transmitted plane polarized light, (X 150).

Figure 13 : 394/10 dolomitic micaceous siltstone (mica elongated parallel to both bedding, S_o, and cleavage, S_2).

The elongation of the mica grains (muscovite) defines both the bedding (S_o) and cleavage (S_2) traces as shown. Larger and more squat micas (ratio width : length of about 1:5) define the bedding trace (S_o). Smaller, thinner and more numerous mica grains (ratio width : length of about 1:12) define the cleavage trace (S_2). The later microstructure is the more pervasive. Figures 12 and 13 can be superimposed using the circled control points.
Transmitted light, crossed polars and in the 45^o position which gives good illumination to micas elongated parallel to bedding and cleavage, (X 150).

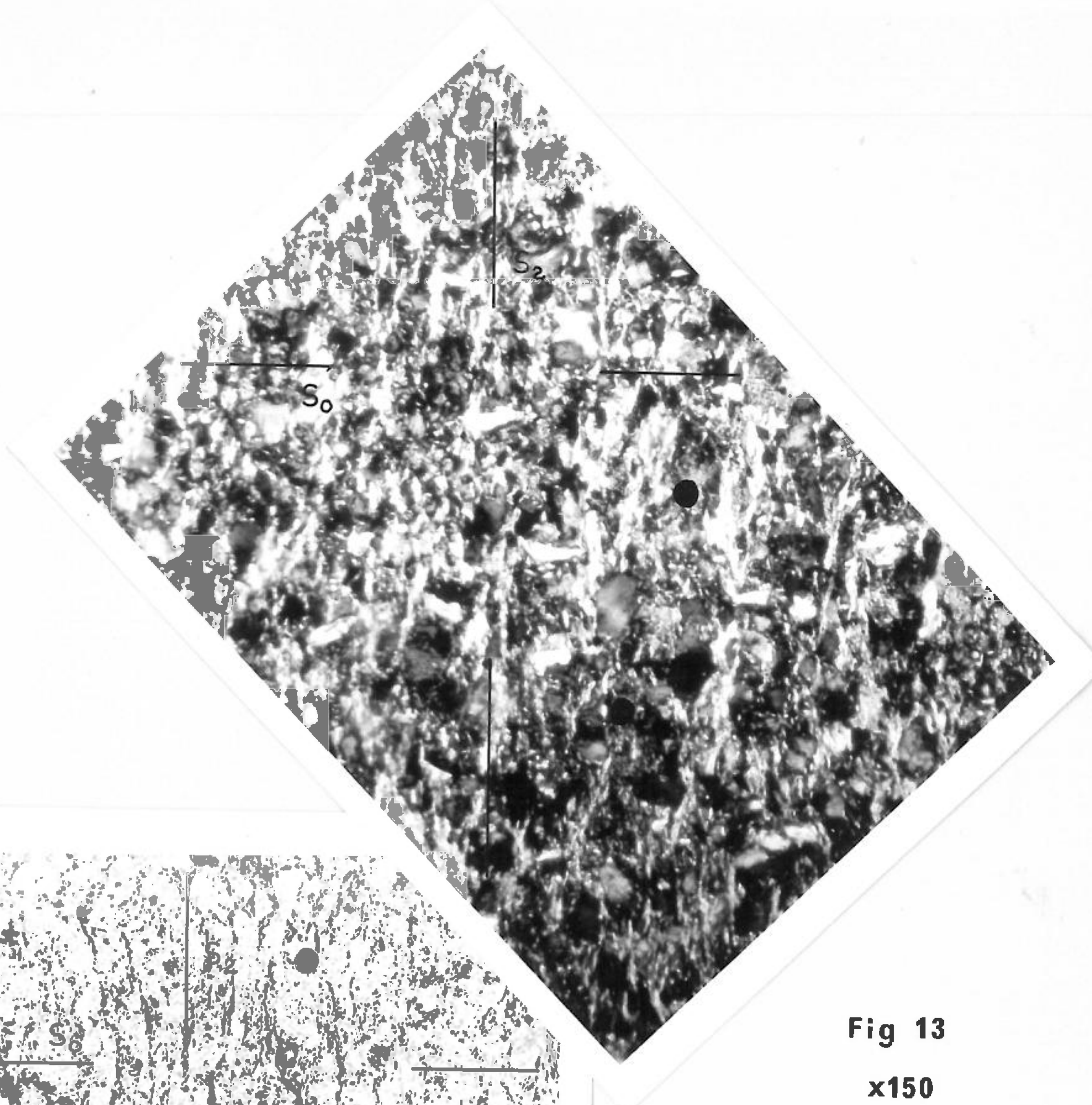


Fig 13

x150

Fig 12

x150

Figure 14 : 394/29 'bedded' pyrite (cleavage, S_2)

Macroscopically this specimen shows a cleavage (S_2) developed in the 'bedded' pyrite. Microscopically the trace of this cleavage is defined by layers of v.f.g. pyrite cutting through disrupted pyrite aggregates, as shown. The elongation of the aggregates defines the trace of bedding. There is some associated cross-crystallized quartz. Reflected light, plane polarized, (X 60).

Figure 15 : 394/18N carbonaceous dolomite (non-pervasive cleavage).

The cleavage trace (S_2) defined by the elongation of carbonaceous material is part of a 'cleavage accentuated flame structure'. The cleavage is only locally pervasive due to a local concentration of a mineral that is capable of defining a cleavage, in this case carbonaceous material. The bedding trace (S_0) is shown by a lighter coloured, more dolomitic layer.
Transmitted plane polarized light, (X 50).

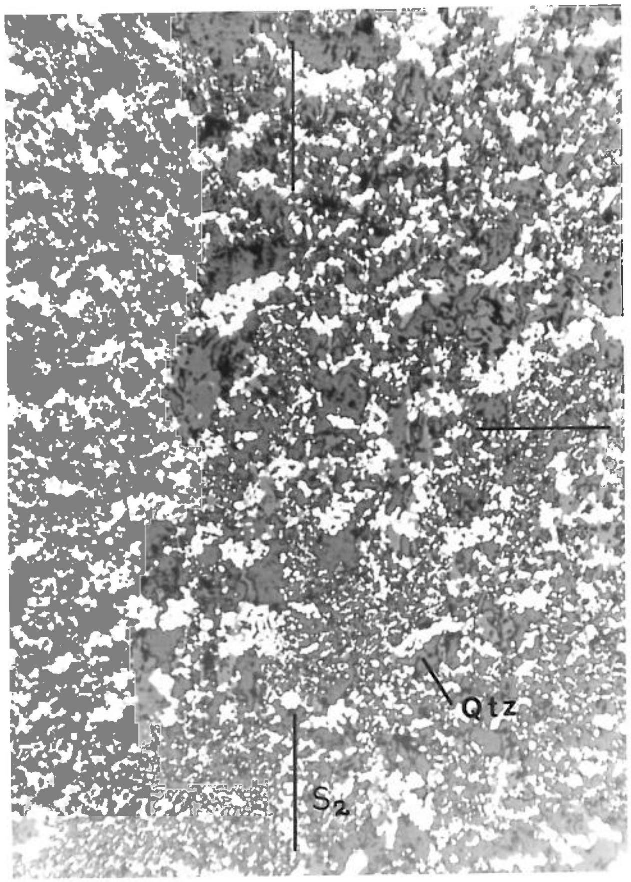


Fig 14

X60

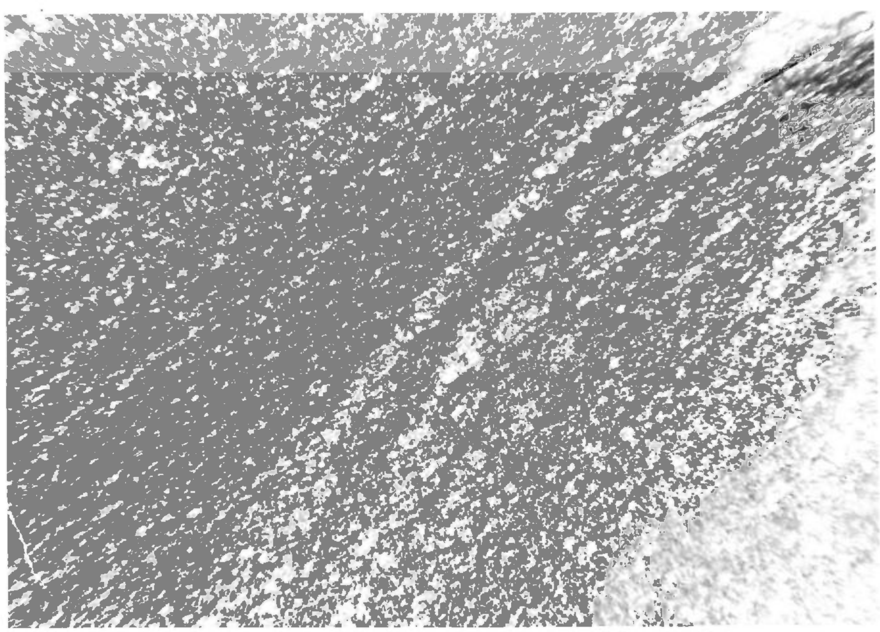


Fig 15 X50

Figure 16 : 394/17N carbonaceous dolomite ('bleb')

The bedding (S_0) passed through the 'bleb'. Also the 'bleb' has affected the local development of the cleavage (S_2). Hence a diagenetic origin of the 'bleb' is postulated. The elongation of the bleb is at a slight angle to the cleavage (c.f. Ramsay, page 408). This change of direction of the bedding trace is thought to be due to its different composition (i.e. different competence) with respect to the host rock. A faint trace of a mica beard elongated parallel to cleavage can be seen at either end of the 'bleb'.
Transmitted plane polarized light (X 60).

Figure 17 : 394/24X 'bedded' pyrite with cross-crystallized quartz.

Cross-crystallized quartz is growing perpendicularly to the 'beds' of pyrite. It is associated with dirty dolomite, is sigmoidal and shows undulose extinction.
The 'beds' of pyrite show some folding (kinking).
Transmitted light, crossed polars. (X 50).

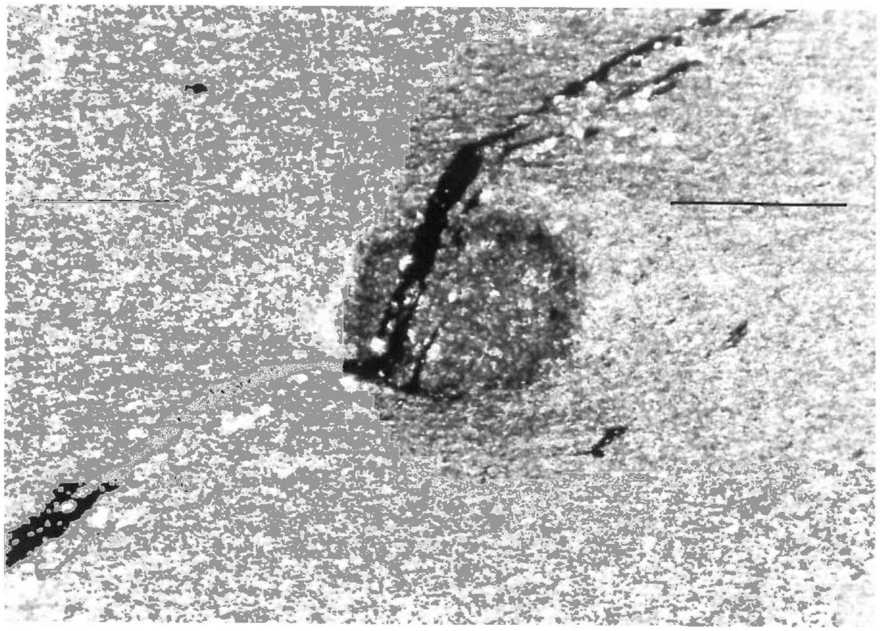


Fig 16 X60

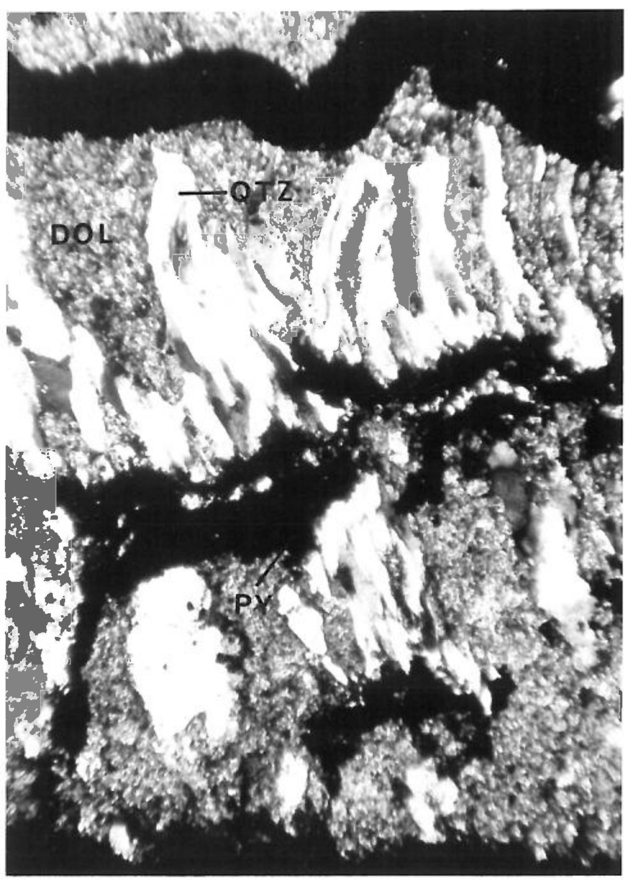


Fig 17

X50

STRUCTURAL ELEMENTS

Mesoscopic folds are only rarely developed within the Lady Loretta area. Only two of the recognized fold groups have axial plane structures that can be consistantly observed in outcrop. The other two are characterized by inhomogeneously developed linear structures on bedding planes and macroscopic, low amplitude folds and warps. The distinction of different fold groups according to; fold style, associated axial plane structures and or by using over-printing criteria is not possible(Hobbs, 1966; Williams, 1971; Williams, Hobbs, Vernon and Anderson, 1971). Instead, the morphology, orientation and the degree of development of linear structures on bedding ~~plains~~ planes (mainly), had to be used to classify the different fold groups. The successful use of these criteria was only made possible by the detailed nature of the mapping carried out, generally at a scale of 1:480 and some at 1:240. It is necessary to define the characteristics of the structural elements measured.

The notation used in this report is given below:

F, refers to a group of folds and the subscrips x associated with it, (i.e. F_x) denotes the group specified.

S, refers to a planar structure.

S_o denotes bedding

S_x denotes the axial plane structure (cleavage) associated with group x folds.

L, refers to a linear structure formed by the intersection of two planar structures.

L_x denotes the linear structure (lineation) associated with group x folds and which was formed by the intersection of S_x and either S_o or S_1. But it will be shown later that S_o and S_1 are macroscopically parallel. Then the lineations defined by the intersections of S_x and S_o, and S_x and S_1, are parallel and both denoted L_x.

It should be noted that the F_x fold axis does not have to be parallel to L_x. This will be discussed later.

S_o - bedding

With reference to the whole Lady Loretta sequence, but excepting the barite-chert rock and possibly some of the lead-zinc mineralization, bedding is defined in fresh rock by: (394/17N, 394/10)

a) a compositional layering of different mineral assemblages (Figs. 12, 15, 16, 17),

b) the elongation and concentration of carbonaceous material (Fig. 12, 16),

c) the elongation of larger and thicker mica grains (Fig. 13), in comparison to those defining S_2.

In outcrop, bedding is commonly expressed by varying limonite impregnation (Fig. 11, 9) and could be confused with limonite associated with liesegang rings and joints.

The barite-chert rock is layered, the characteristics of which are discussed below. However, it is relevant to establish that sedimentary barite deposits can occur. Brobst (1965) classified barite deposits into three types:

a) vein and cavity filling deposits,

b) residual deposits,

c) bedded deposits.

The bedded barite deposits described by Brobst have the following characteristics:

a) lensoid, with both sharp and gradational contacts with clastics,

b) fine grained, fetid and grey,

c) associated with quartz, chert, pyrite, dolomite, calcite, witherite, strontianite and clay minerals,

d) contains organic material.

The majority of these characteristics are also common to the barite-chert rock occurring in the Lady Loretta area.

S_1 and L_1 - barite layering (F_1 cleavage) and rodding (L_1)

S_1 defines the axial plane of chert folds (F_1 folds) in the Barite-Chert Rock (Fig. 2, 394/08). It is commonly so well developed that the original chert beds of the barite-chert sediment have been transposed to lensoid bodies surrounded by a layered barite plus quartz matrix. One small outcrop was found where this layering (S_1) has not completely destroyed the original bedding (Fig 3). The intersection of S_o and S_1 defines a chert and or quartz rodding (L_1) (Fig. 4) which is parallel to the fold axes of the chert folds (F_1). Microscopically the S_1 trace is defined by the elongation of barite grains (Fig. 5) and S_1 is defined compositionally by lensoid masses of chert, sphalerite, pyrite and barite plus quartz. Differential weathering of the barite from the surface of outcrops accentuates S_1 and L_1, as they are expressed by quartz aggregates and chert.

The Barite-Chert Rock is the only lithology in which these structural elements have been observed. However, the author feels that some of the layering observed in cored high grade lead-zinc mineralization (394/34) may be S_1 and not S_o, it looks transposed.

S_2 and L_2 - slaty cleavage (F_2 cleavage) and associated lineation (L_2)

Three mutually perpendicular sections were cut from a number of fresh rocks (S section : parallel to cleavage, N section : perpendicular to both bedding and cleavage, P section : perpendicular to cleavage and parallel to the cleavage/bedding intersection). In doing so it was hoped to find evidence for the axial plane structures of the four groups of folds recognized. Only two microstructures were consistently observed; (394/17N, 394/10, 394/18N, 394/29)

a) one parallel to bedding (described above),

b) one defining S_2 and inclined to bedding.

There is also only one consistently observable cleavage developed in the outcropping rocks, with the exception of the Barite-Chert Rock.

The S_2 trace is defined in fresh rock by:

a) the elongation of carbonaceous material (Fig. 12, 15, 16),

b) the elongation of smaller and thinner mica grains (Fig. 13) in comparison to those defining S_o,

c) the elongation of beards associated with the 'blebs' (Fig. 16),

d) layers of very fine grained pyrite cutting through pyrite grain aggregates defining bedding (Fig. 14),

e) elongation of sphalerite and galena aggregates (394/27X).

The carbonaceous material defining S_2 appears to have redistributed from concentrations that define S_0 (Fig. 12). Muscovite, paragonite and chlorite are the main micas defining the slaty cleavage, S_2. The pervasiveness of cleavage within the Lady Loretta area is dependent on:

a) the supply of carbonaceous material and or the ability of the lithology to grow micas during metamorphism associated with folding ~~deformation~~ (Fig. 15),

b) the intensity of the deformation.

The former variable is thought to be operative when only a non-pervasive S_2 microstructure is developed in a rock. The latter is thought to control the development of S_3 and S_4. The slaty cleavage (S_2) has the additional property of being divergent, as is shown in Figure 8.

It has been observed that within the Lady Loretta area limonite preferentially replaces carbonaceous material during weathering. A polished section of a very limonitic siltstone (394/37) cut perpendicular to cleavage showed that limonite had replaced the matrix of the rock and in doing so preserved the S_2 trace. The micas are thought to be replaced along with the carbonaceous material only when the ferrugination is intense. Then on differential weathering the more resistant limonite is accentuated. In the event of silicification, the greater the replacement of the matrix the more pronounced is the resistant secondary chert on differential weathering, in comparison to the original detrital grains (Fig. 10). In the case of only limited ferrugination and silicification, the micas decompose to clay minerals and impart a poor fissility to the rock that is parallel to cleavage (S_2) (Fig. 11, 7).

The intersection of S_2 and S_o defines the lineation L_2. Apart from the fact that most of the outcropping bedding planes are limonitic and therefore generally have a well defined homogeneously developed L_2 on them, there is a minor slip component associated with S_2 which is expressed as small ridges on the S_o surfaces (Fig. 7). The intersection of S_1 and S_2 also defines L_2 and is expressed as an inhomogeneously developed crenulation on the barite layering (S_1) (Fig. 4).

<u>S_3 and L_3, S_4 and L_4</u> - (F_3 and F_4 cleavage and associated lineation)

S_3 and S_4 were not observed in the mutually perpendicular sections cut from fresh rock. However, poorly developed S_3 traces on outcropping joint planes were sometimes measurable (Fig. 10). Unfortunately any cleavage that may have been developed by F_4 is approximately co-planar with S_2. Therefore S_4 was only measured when both S_4 and S_2 were distinguishable (for example around 6630N 490W, Fig. 6).

The intersection of S_3 and S_4 with either S_o or S_1 defines the lineations L_3 and L_4 respectively. In the Barite-Chert Rock, L_3 and L_4 are expressed as an inhomogeneously developed elongation of quartz grain aggregates (Fig. 4). Chert plus these aggregates define the more macroscopic rodding (L_1). Differential weathering of the barite from S_1 has helped to accentuate these disjoint linear structures. L_3 and L_4 are defined in a similar way to L_2 in the remainder of the outcropping lithologies. However, they are not as well developed, nor are they as homogeneously developed. Generally where L_2 is well developed, L_3 and L_4 are only poorly developed. This is commonly the case for the Upper and Lower Limonitic Shales and Siltstones. Also, where L_2 is only weakly developed, but still homogeneous, L_3 and L_4 are better developed, as is the case for the more silicified lithologies mapped.

L_3 and L_4 can be easily distinguished from one another on the basis of orientation:

L_3 ; directed towards about 140° or 320°

L_4 ; directed towards about 230° or 050°

Due to;

a) the almost continuous outcrop from one area to another and

b) the detailed nature of the structural mapping (an average of 3 structural elements measured per station per 90 square meters of outcrop), it was possible to observe the gradual variations of the linear elements along strike. Generally this control on the orientation of the lineations (L_2, L_3 and L_4) from one outcrop to the next was sufficient to unambiguously classify them from one area to another and in areas where they are almost equally developed.

Because L_3 and L_4 are defined by morphological characteristics similar to L_2, it is suggested that S_3 and S_4 are probably defined by a non-pervasive carbonaceous microstructure. This is possibly the result of very low grade metamorphic events associated with the F_3 and F_4 deformations, rather than the inability of the lithologies to develop a better microstructure. Then it was fortunate that the sequence is carbonaceous, as this material is thought to be able to redistribute at low temperatures (Landis, 1970) and develop an axial plane structure. It was also fortunate that the Lady Loretta rocks, aided by favourable weathering conditions, were able to both preserve and accentuate the non-pervasive cleavages associated with the F_3 and F_4 deformations to such an extent that they are recognizable in outcrop.

STRUCTURAL ANALYSIS

Over Printing Relationships

Over printing relationships observed in the field suggest that the order of fold deformation within the Lady Loretta area was from F_1 to F_4.

Both L_2 and L_3 are redistributed around F_4 folds, figure 6. L_2 is redistributed by F_3 folds, figure 7. Two outcrops (6150N 1140W; 6210N 1130W) were found where the barite rodding (L_1) was folded around an axis towards 030°, the common direction for the F_2 fold axis. However, this is not considered to prove that F_2 post-dates F_1 as F_1 and F_4 are very close in direction (030° vs 050°). A better criterion to use is the crenulation of the barite layering (S_1) by the F_2 cleavage, figure 4.

Data

An attempt was made to collect data at an even density on outcrop south of the Carlton Fault and east of the Syncline Dividing Fault (plate 2). Outcrops on which a greater number of structural elements were measurable and or better developed were favoured. The author had not recognized the development of F_3 and F_4 structural elements until about half of the mapping had been completed. Some areas were re-covered for these elements but unfortunately the overall coverage is not complete. A number of areas were mapped in greater detail:

a) all Barite-Chert Rock outcrops;
6960N 1810W
6650N 1470W
6820N 400W
and <u>especially</u> 6300N 1200W
and 5550N 1100W (at a scale of 1:240),

b) the trenches; 7200N 970W
7600N 1250W
and one off the map (plate 1) to the north-east, (data collection every 3 m),

c) the outcrop between 5700N 1100W and 5700N 700W,

d) the domal structure centred around 6000N 1400W,

e) the F_3 fold around 6450N 1400W,

f) the F_4 fold around 6620N 500W (some at a scale of 1:240).

It was hoped that this detailing would provide statistical plots of redistribution relationships of earlier structural elements (assumed to be initially homogeneous within a small area) around later folds, the associated structural elements of which were hoped to be homogeneous with respect to still later folding. Unfortunately, plots of this data commonly indicated that the assumptions were unjustified.

Assumptions

The following assumptions are made in the interpretation of the data:

a) The sequence is assumed to conform to the classical layer-cake geological model. It has already been suggested before that this model is not applicable to the Lady Loretta area. Then any anomalies arising from the interpretation will support this suggestion of a non-classical layer-cake geological model for the sequence.

b) All the folding is considered to be the result of homogeneous strains. It is not possible to check this assumption.

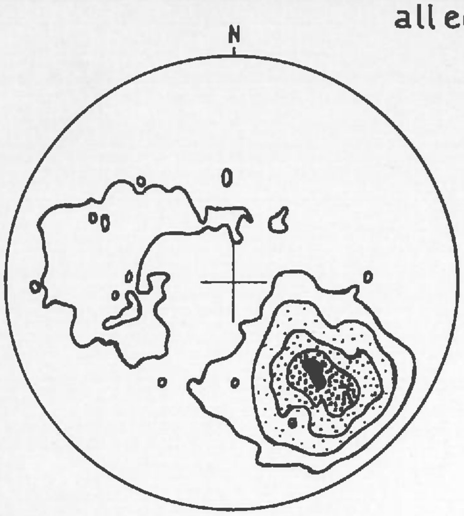
c) The order of fold deformation was observed to be F_1 to F_4 using overprinting criteria. This order is assumed to be correct and any errors in it should be apparent from the plots. The directions of these folds are:

F_1 : commonly down dip
F_2 : 030° / 210°
F_3 : 140° / 320°
F_4 : 050° / 230°

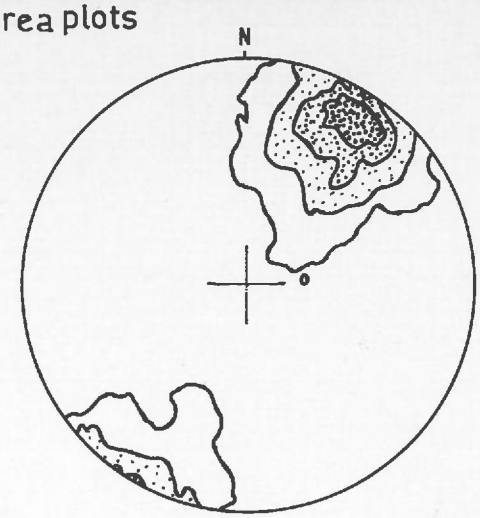
d) The Carlton and Syncline Dividing Faults (plate 2) define the limits of the area to the north and west. Numerous faults of only minor displacement have been indicated by diamond drilling within the Lady Loretta area. The Pof Fault is much larger with an associated stratigraphic displacement of at least 100 m. It is assumed that all the faults within the Lady Loretta area do not have any associated rotational component. Then faults can be effectively ignored since structural elements will remain parallel across them.

e) The assumption is also made that for a fold with a fanned cleavage as its axial plane structure, the intersection of the cleavage planes defines either the ϵ_2 (intermediate) or ϵ_3 (minimum) finite strain direction, irrespective of the original orientation of the layer that shows the folding. Then the fold axis of this layer is not parallel to either ϵ_2 or ϵ_3, excepting when the relevant direction (ϵ_2 or ϵ_3) lies within the ~~plane of its~~ original orientation of the plane. The finite strain directions can be locally modified as "in a parallel-folded multi-layered sequence with high viscosity contrasts and at low to moderate compressive strains" (Roberts, 1971), but macroscopically and for a homogeneous sequence of rocks, such as the Lady Loretta sequence (excepting for the mineralized rocks), the above relationship is thought to hold.

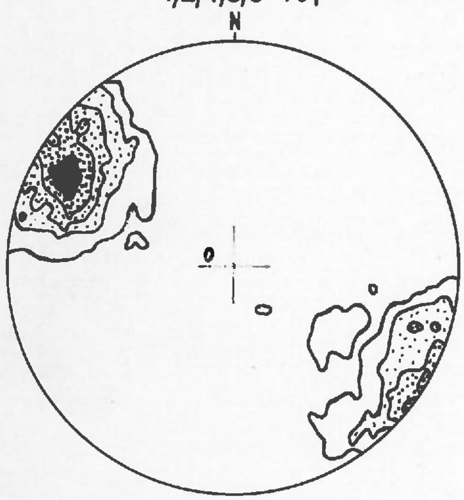
all equal area plots



TOTAL S_0
1305 plots
1,2,4,6,8 % per 1%



TOTAL L_2
1117 plots
1,3,6,9 % per 1%



TOTAL S_2
254 plots
1,3,6,9,12 %
per 1%

F_2 FOLD GEOMETRY

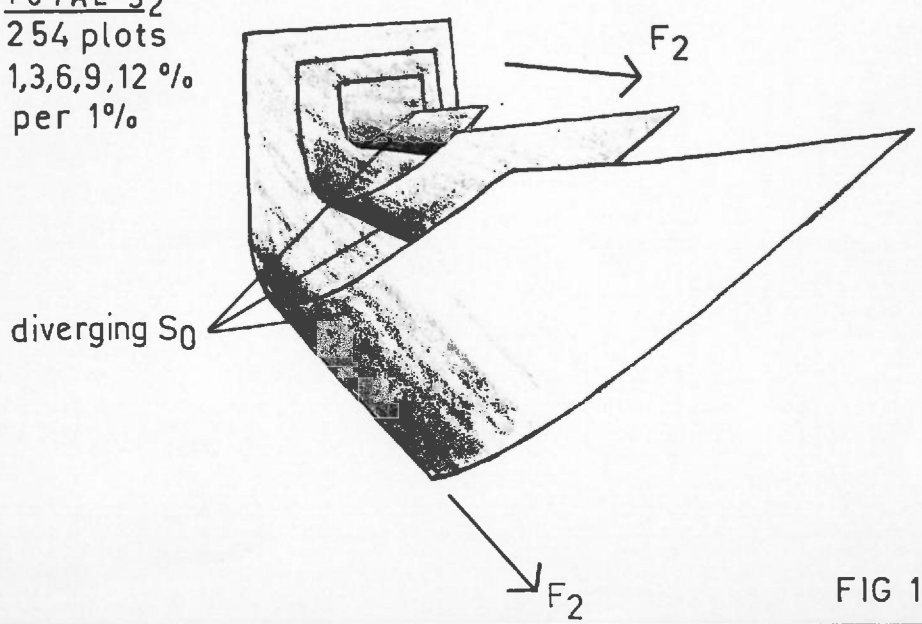


FIG 18

Analysis of The Data

Evidence for 4 groups of folds can be seen in the Barite-Chert Rock and for only 3 groups in the rest of the sequence. The data from these two rock types is therefore treated separately. All the plots referred to are from measurements made on host rocks unless stated otherwise. Please refer to plates 1 and 2.

Macroscopic Geometry (F_2)

With reference to the total plots of S_o, L_2 and S_2 of figure 18. The total plot of S_o has the following characteristics:

a) there is a ratio of data, west dipping: east dipping of 5:2,

b) the two maxima, define a plane, the pole of which coincides with the L_2 total plot maxima, and also suggest a shear style of folding of S_o,

c) the distributions of L_2 and S_o are complimentary

Then the macroscopic structure of the area is an F_2 syncline with average limb dips of about 45°, and with an associated anticline to the west. However because of the unknown control by faulting within the area mapped, the macroscopic structure should be referred to as being synclinal. The distribution of L_2 is a direct result of irregular bedding which could be caused by either or both of:

a) a non-classical layer-cake geological model,

b) earlier or later fold deformations.

The L_2 maxima is 14° - 034° compared with an average plunge of about 30° - 030° for the mineralized rock, as is indicated from exploration diamond drilling. A number of explanations can be suggested for this anomalous situation, the more feasible ones being:

a) an error in the subsurface interpretation of ~~from~~ diamond drilling data,

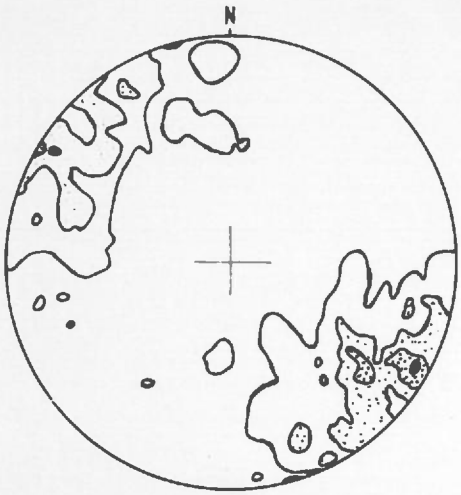
b) an increased plunge due to rotational components associated with faulting,

c) diverging bedding northward, due to an increase in thickness of the units above the Mineralized Rock unit,

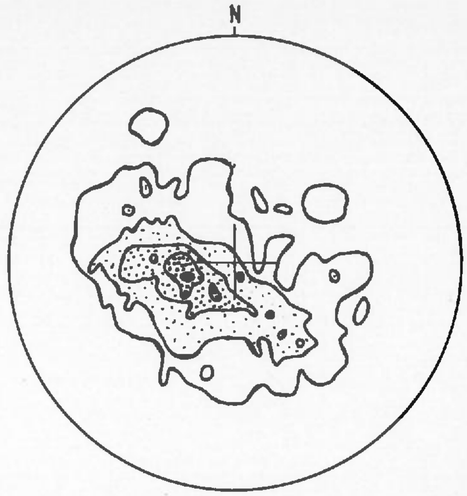
d) the L2 maxima should be parallel to the line of intersection of the fanned cleavage (S2),

The author favours the latter 2 suggestions, although it is possible that all ~~three~~ four may contribute. Then the macroscopic model of the syncline is one of increasing plunge for beds that are lower in the sequence, as is shown in figure 18. Analysis of the structural data with respect to particular stratigraphic units and fault blocks should either confirm or suggest a better explanation for this anomalous situation.

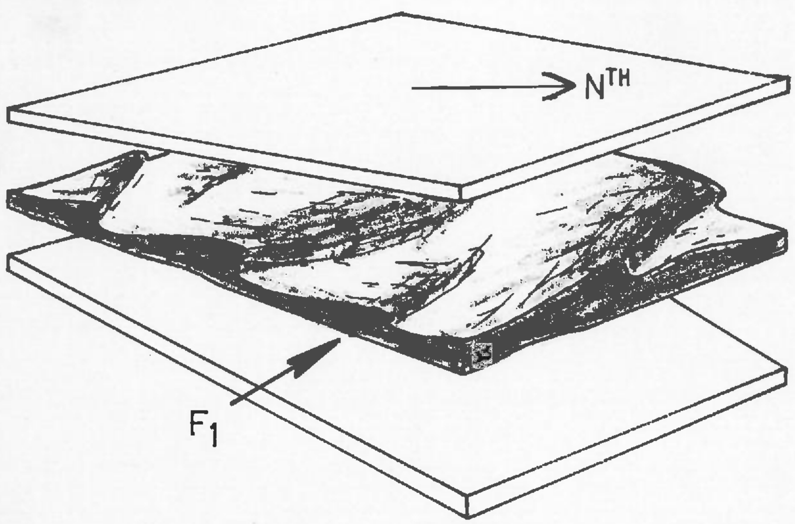
all equal area plots



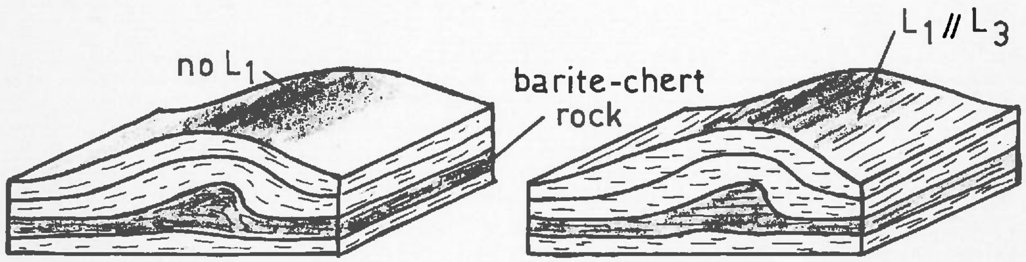
TOTAL BARITE LAYERING, S_1
175 PLOTS
1,3,6,9% PER 1%



TOTAL BARITE RODDING, L_1
183 PLOTS
1,3,6,9,12% PER 1%



F_1 INTRAFORMATIONAL SLUMPS



$S_0 // S_1$.

FIG 19

The L_2 distribution lies in the plane corresponding to the S_2 maxima. S_2 is seen to be fanned about F_2 (Fig. 8) and defines an e_2 or e_3 direction of 06° - 030°. But the F_2 folds are regionally developed and it is therefore thought reasonable to assume that the e_1 and either the e_2 or e_3 directions were originally horizontal. This implies that any combination of the conditions below were possibly operative:

a) The original sedimentary basin in which the mineralized beds were deposited had a slope of <u>at least</u> 10° to the north (possibly more).

b) The sediments subsided to a greater extent to the north, especially after the deposition of the mineralized beds.

c) Faulting that was penecontemporaneous and or pre-F_2 folding occurred on the Carlton Fault.

Significance of F_1

With reference to the total plots of S_1 (barite layering) and L_1 (barite rodding) of figure 19 and L_2 of figure 18. L_1 is approximately:

a) parallel to L_3,

b) perpendicular to L_4,

and is significantly redistributed by neither F_3 folding nor by the low amplitude F_4 folding. Then the distribution of L_1 about a plane is thought to be primarily due to F_1 folding. S_1 should also be folded by F_2 to give a fold

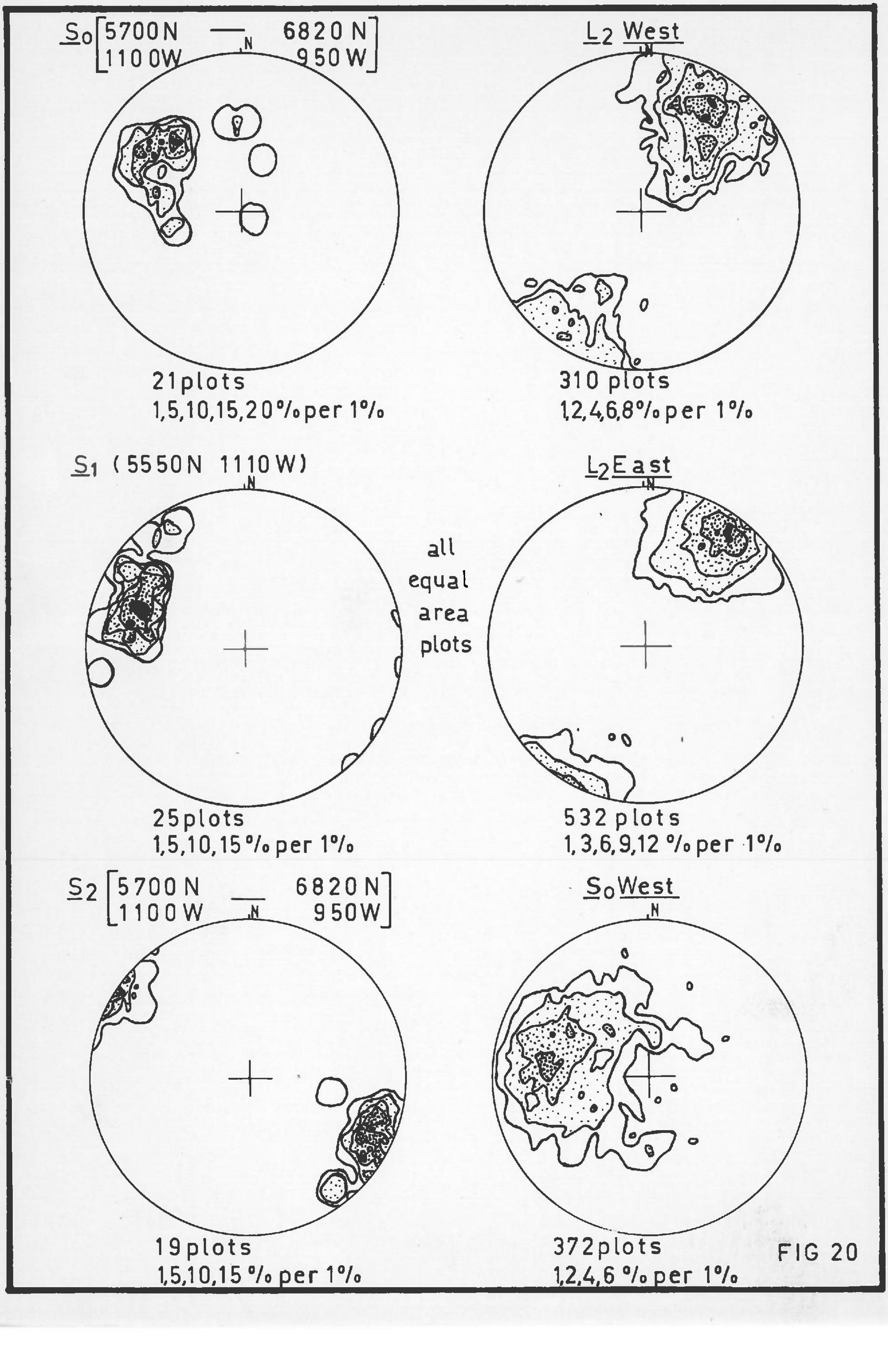

S0 [5700N 1100W — N 6820N 950W]
21plots
1,5,10,15,20%per 1%
L2 West
N
310 plots
1,2,4,6,8%per 1%
S1 (5550N 1110W)
N
25plots
1,5,10,15%per 1%
all equal area plots
L2 East
N
532 plots
1,3,6,9,12 %per 1%
S2 [5700N 1100W — N 6820N 950W]
19plots
1,5,10,15 % per 1%
S0 West
N
372plots
1,2,4,6 % per 1%

FIG 20

axis lying in the average S_2 plane. This is true, but the fold axis is coincident with the L_2 distribution and therefore the implication is that S_o and S_1 are <u>macroscopically</u> parallel. Figure 3 illustrates that S_1 and S_o can be <u>locally</u> discordant.

S_1 and S_2 are the best developed secondary planar structures in the Barite-Chert Rock and host rocks respectively. Then if it was not for the fact that the author can recognise linear structures on the S_1 surface (Fig. 4) that are genetically related to the F_2, F_3 and F_4 deformations, there would be a temptation for correlating S_1 and S_2. This would be especially true for the largest outcrop of the Barite-Chert Rock (6300N 1200W) where S_1 is commonly dipping steeply to the west, which is also the likely orientation for S_2 within this area. But with reference to figure 20; the plot of S_1 for the outcrop around 5550N 1100W and for S_2 and S_o between 5700N 1100W and the F_2 fold hinge at 6820N 950W, clearly shows that S_1 and S_o are macroscopically parallel.

The following are thought to be relevant to the interpretation of the Barite-Chert Rock:

a) The F_1 deformation has only been recognized in the Barite-Chert Rock.

b) Diamond drilling has shown that this rock type is not always developed and can be extremely variable in thickness. This can also be seen from the outcrop pattern of the Barite-Chert Rock.

c) It can be associated with shearing and brecciation such as at 7000N 360W (Silicified Breccia), but it is not always associated with it, and neither is the 'bedded' lead-zinc mineralization when the barite-chert rock is not developed.

d) All stages of transposition of the original barite plus quartz and chert bedding have been observed (S_1 intersecting S_0, to S_1 as an axial plane structure to chert folds, to S_1 as a layering around transposed chert lenses).

e) The lead-zinc mineralization (thought to be equivalent to hematite in outcrop) is highly contorted and the high-grade mineralization sometimes <u>appears</u> to be <u>transposed</u> (parallel to bedding).

f) The <u>lobes</u> in the hematite outcrop to the east (e.g. 6100N 360W) and referred to before, have flat bases and irregular tops and in cross-section look like large slump structures that have moved to the <u>north</u>.

g) It was suggested above that either the original depositional basin dipped significantly to the north or such dips developed soon after deposition via subsidence and or ~~pre~~ pene contemporaneous faulting.

h) There is a high density contrast between the mineralized rocks and the host rocks (1 - 1.5 gms/ml.)

i) The order of increasing incompetancy for the mineralized rocks is thought to be; 'bedded' pyrite, 'bedded' lead-zinc mineralization, barite-chert rock.

Since S_1 is parallel to S_0 and is unique to the one lithology, it is interpreted to have formed as a consequence of differential movement about this one rock type. This movement was in a direction perpendicular to the barite rodding (L_1), that is to the north or south. The F_1 deformation could then have been:

a) associated with a thrust plane, or

b) caused by intraformational slumping.

The features outlined above that are thought to be relevant to the interpretation suggest that the latter occurred and in association with the lead-zinc mineralization. The author feels that an increase in the dip of the more dense mineralized rocks after deposition (possibly during early diagenesis) caused them to become unstable (Ross, 1971) and flow plastically to the north. The barite-chert rock and some of the high-grade lead-zinc mineralization was transposed while the other lead-zinc mineralization was possibly contorted and boudinaged. It is possible that some shearing parallel to S_0 occurred locally. The barite rodding (L_1) is thought to have formed parallel to the fronts of the slumps. Then a variable orientation of L_1 before F_2 folding is possible ~~as~~ and it is likely that the slumps were discontinuous in their development. This does not significantly alter the interpretation of the L_1 distribution as the ratio of the number of plots from the large Barite-Chert outcrop : smaller one to the south : the rest of the outcrops, is 7:1:1. The former two are thought to be related to the same slump and then it is likely that L_1 was homogeneous before F_2 folding. The data from these two areas is responsible for the distribution. An ideal geometric model of the sediments before F_2 folding is given in figure 19.

With S_o parallel to S_1, it is possible that the mica and carbonaceous material microstructure that defines bedding may in actual fact be an expression of S_1 in the host rocks. If so, the mica microstructure will not be developed in sediments deposited after the slumping has occurred. Such a microstructure could have also formed from either detrital micas and or diagenetic growth during loading. A microstructure should be developed in the slumped material of the Cyclic Beds unit if the latter is responsible (the microstructure in 394/19N is unfortunately inconclusive). These relationships require checking, because if the microstructure is genetically related to S_1, then it is possible to form an expression of L_1 on the host rock S_o in the immediate vicinity of the intraformational slump (figure 19). But as L_1 and L_3 are approximately parallel, it is likely that they would be confused and attributed to the same deformation.

Group 4 Folds

With reference to the total plots of L_4 and S_4, figure 21. As F_4 was the last fold deformation within

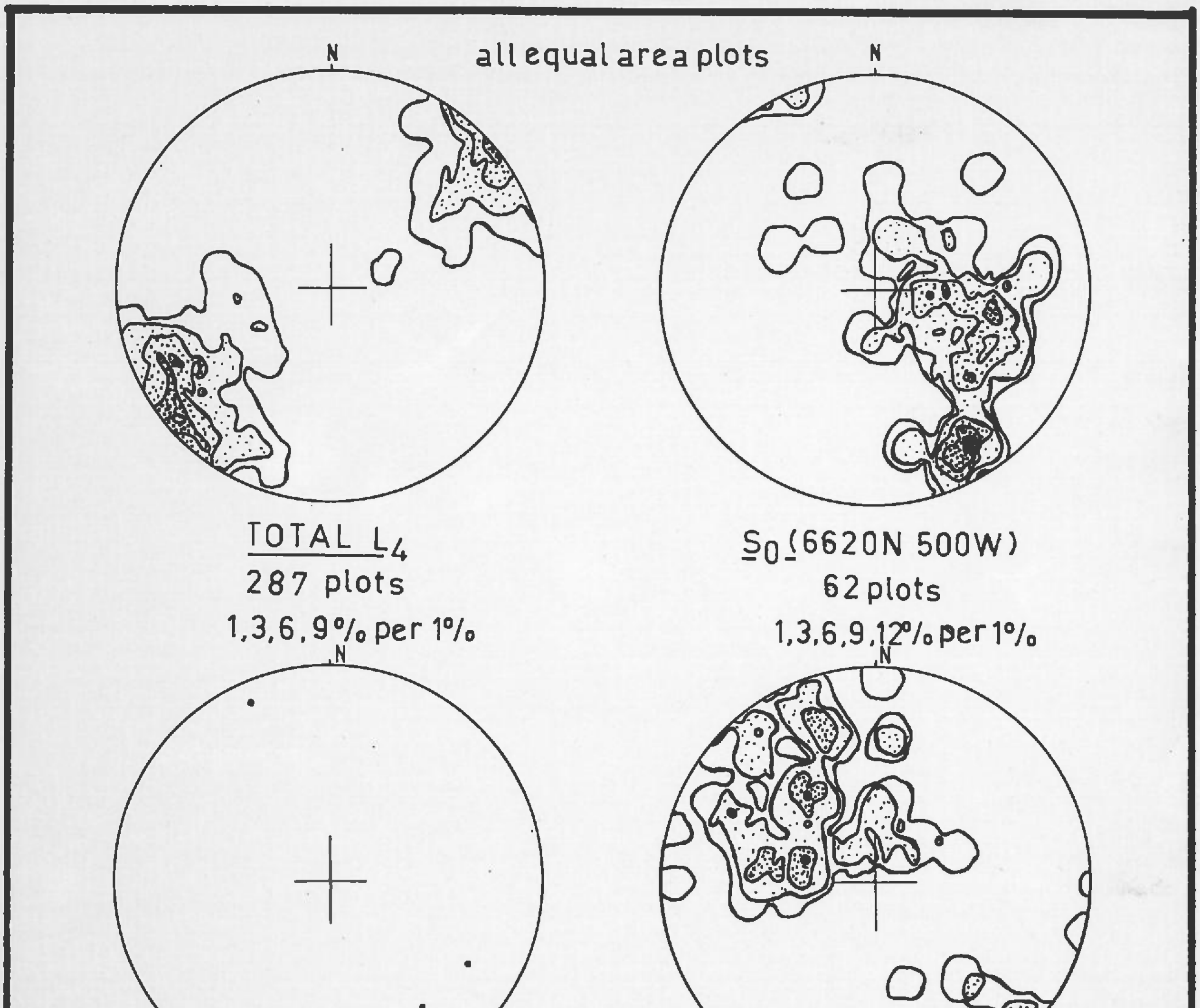

all equal area plots
N
N
TOTAL L_4
287 plots
1,3,6,9%per 1%
S_0 (6620N 500W)
62 plots
1,3,6,9,12%per 1%
N
N
TOTAL S_4
L_3 (6620N 500W)
61 plots
1,3,6,9%per 1%
east
limb
F_4
F_2
F_4 FOLD GEOMETRY

FIG 21

the area, L_4 should be distributed about the S_4 plane(s). The total plot of L_4 has the following characteristics:

a) a maxima of 03° - 231°,

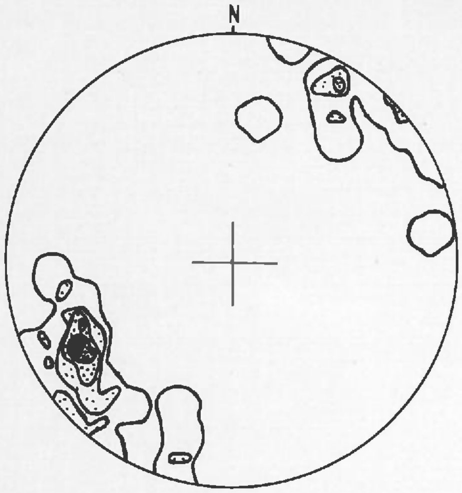
b) a distribution suggestive of a fanned cleavage.

The three plots of S_4, although insignificant, do not contradict the suggestion of a fanned F_4 cleavage.

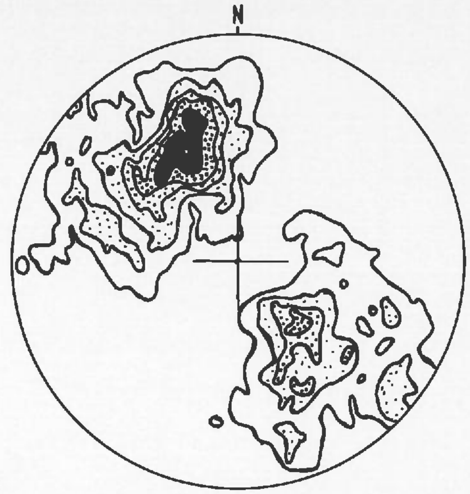
Only 3 small F_4 folds were found within the area mapped; 6620N 500W, 6090N 1290W and 7000N 1700W. This group of folds was initially recognized at the former locality (Fig. 6). Also, macroscopically the eastern limb of the syncline has a broad warp in it which is not in sympathy with any of the F_1, F_2 nor F_3 deformations. It is attributed to an F_4 deformation.

Plots of S_o and L_3 around the former F_4 fold mentioned above are given in figure 21. S_o illustrates two poorly developed maxima that are suggestive of a shear style of folding for F_4. L_3 is very poorly distributed about a girdle. It will be shown below that the plots of L_3 measured on west dipping beds are generally widely distributed. Also the assumption of homogeneity is not thought to be strictly applicable to this area. The geometry of the F_4 fold on the eastern limb of the syncline is illustrated in figure 21.

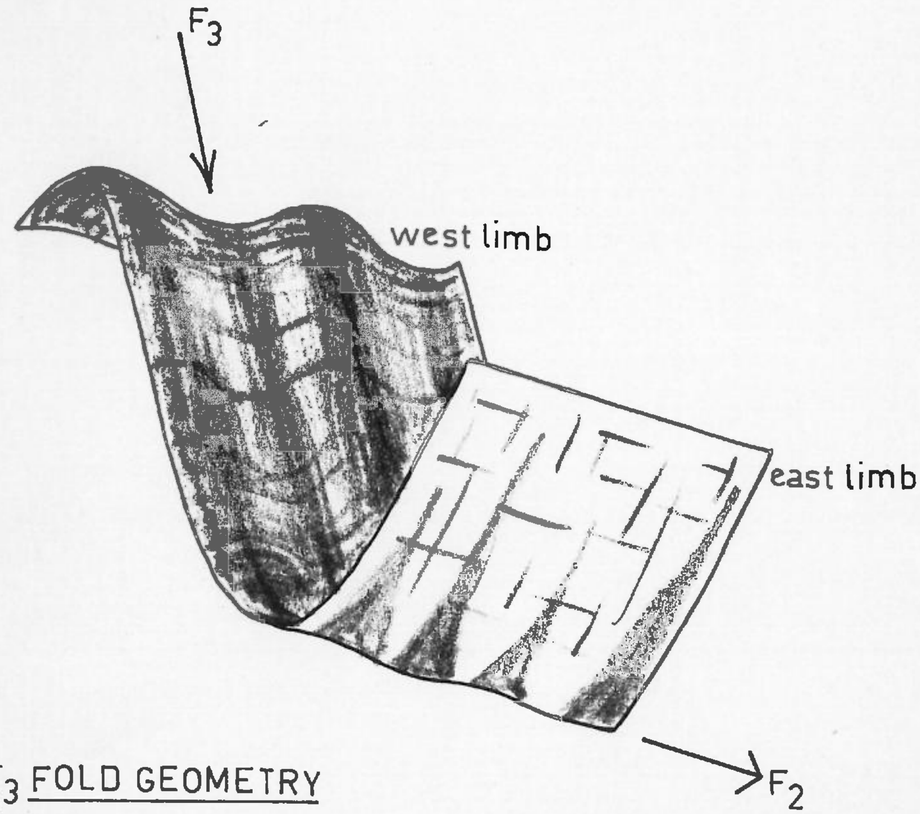
all equal area plots



TOTAL S_3
24 PLOTS
1,5,10,15,20% PER 1%



TOTAL L_3
387 PLOTS
1,2,3,4,5% PER 1%



F_3 FOLD GEOMETRY

FIG 22

Group 3 Folds

With reference to the total plots of L_3 and S_3, figure 22. Although only 24 measurements were made of S_3 the plot distribution does suggest a fanned cleavage with an e_2 or e_3 direction of about 40° - 131°. It is noted that the e_2 or e_3 direction is approximately:

a) parallel to S_0 on the western limb of the syncline,

b) perpendicular to S_0 on the eastern limb of the syncline.

Then S_0 will express F_3 folds on the western limb but not on the eastern limb (Ramsay, 1967, 7-11). This relationship is seen to be valid from plates 1 and 2 where the western limb is contorted by F_3 folding while the eastern limb is relatively straight.

The bias of L_3 measured on the western limb : eastern limb is 3:5. The two L_3 maxima mimic the intersection of S_3 with the limbs of the synclines. Then assuming no significant redistribution of L_3 by F_4 folding, the distribution of L_3 is suggestive of a fanned cleavage in that:

a) there is a generally wide distribution of L_3,

b) the distribution of L_3 is greater on the eastern limb.

For the e_2 or e_3 direction as predicted by S_3, a single maxima would be expected of a plot of east plunging L_3 measurements. This is the case and it is a better approximation to the e_2 or e_3 direction (57° - 137°) in view of the greater number of L_3 measurements used with respect to those of S_3. The above interpretation of L_3 ignores the possibility of a L_1 (approximately parallel to L_3) linear structure being developed in the host rocks.

With reference to the western limb plots of S_o and L_2 and the eastern limb plot of L_2, figure 20. The L_2 distribution is greater for the western limb and is attributed to the development of both F_1 and F_3 folds on this limb compared with only F_1 folds on the eastern limb. This relationship suggests that e_3 and not e_2 is directed approximately perpendicular to the bedding of the eastern limb. Redistribution of L_2 by F_4 folding is assumed negligible. The S_o plot illustrates the inhomogeneity of the western limb bedding. Distributions of it according to F_1, F_2 and F_3 folding can be observed.

The best illustration of F_3 folding is the domal structure (intersection of F_2 and F_3 anticlines) centred around 6000N 1400W. It can be seen from plate 2 that the Barite-Chert Rock appears to be associated with the F_3 synclines, suggesting that the intraformational slumps have locally controlled the development of the F_3 folds. The geometry of the F_3 folds is illustrated in figure 22.

SUMMARY

It was the aim of this study to document the folding of the Lady Loretta area and its relationship to the compositional and thickness variability of the mineralized rocks. The ultimate objective of the author was to produce a structural model of the Mineralized Rock unit, which must be necessarily ideal, but helpful as a visual aid to understanding this unit.

The geological history of the Lady Loretta area and its relevance to the geometry of the Mineralized Rock unit is given below:

a) <u>Sedimentation</u> occurred in an environment favourable to the deposition and or early diagenetic development of;

   1) detrital material, carbonaceous material, dolomite and tuffites,

   2) sulphide mineralization, mainly pyrite, sphalerite and galena,

   3) barite, quartz and chert.

   The thickness of this sediment varies locally and is thought to increase   to the north, either as a result of greater subsidence northwarl or due to penecontemporaneous faulting (Carlton Fault?) or both.

b) During diagenesis, 'blebs', cross-crystallized quartz and mica (elongated parallel to bedding) developed. A northerly increase in the dip of the Mineralized Rock unit caused it to become unstable with the subsequent formation of intraformational slumps (F_1 deformation). The affect on the mineralized rocks was variable:

1) Folding (contorting), boudinaging and some transposition of the 'bedded' lead-zinc mineralization.

2) Transposition of the barite-chert rock by ductile flow to produce a layering, which is macroscopically parallel to bedding, and an associated rodding thought to be locally parallel to the front of the slumping.

3) Minor boudinaging and warping of the 'bedded' pyrite.

These slumps are thought to be irregular in size and only locally developed, as is shown in figure 19. Associated faulting/shearing is thought to have been uncommon.

c) The second phase of fold deformation, F_2, was associated with a greenschist facies (chlorite zone) metamorphic event. This deformation is responsible for the macroscopic geometry of the area (i.e. syncline with an associated anticline to the west). F_2 folds are characterized by:

1) a cleavage defined by mica (muscovite, paragonite, chlorite), carbonaceous material and redistributed pyrite,

2) a fanned slaty cleavage,

3) fold axes directed towards 032°/212°,

and is probably responsible for:

1) the limited recrystallization of the lead-zinc mineralization,

2) the sphalerite/other sulphide grain boundary equilibrium,

3) galena and sphalerite veining,

4) the bending of the cross-crystallized quartz,

5) some of the small scale folding of the 'bedded' lead-zinc mineralization.

The macroscopic geometry of the Mineralized Rock unit (assuming it to be a flat sheet) after the F_2 deformation is shown in figure 18. The important feature of this geometry is that the plunge of the fold axis of the rocks in the core of the syncline is at least 10° less than that for the Mineralized Rock unit.

d) A further fold deformation of the area, $\underline{F_3}$, is characterized by an e_2 or e_3 direction which is:

1) approximately parallel to the western limb of the syncline and therefore the bedding is foleed according to F_3,

2) approximately perpendicular to the eastern limb of the syncline and therefore the bedding does not show any F_3 folds.

This geometry is illustrated in figure 22. Locally the barite rodding and F_3 fold axes (directed towards $148^{\circ}/328^{\circ}$) are parallel. The barite-chert slumps appear to have locally controlled the development of the F_3 folds on the western limb as all the F_3 synclines exclusively contain this rock in their core in outcrop.

e) The last fold group recognized, $\underline{F_4}$, has only locally developed small amplitude folds and larger warps (Fig. 21), with fold axes directed towards $051^{\circ}/231^{\circ}$. Both F_3 and F_4 are characterized by very poorly developed cleavages, thought to be defined by carbonaceous material.

f) Very little is known about the <u>faulting</u> within the area. It could have occurred at any time. A <u>possible</u> interpretation of ~~the faulting~~ it is given in plate 2.

g) Oxidation has occurred to a depth of about 100 m and leaching to about 200 m. Deeper oxidation and leaching is associated with shearing and fault zones, the deepest being about 500 m. Silicification and ferrugination of the favourable mineral assemblages in a favourable climate is thought to have been responsible for the preservation and accentuation of the generally poorly developed structural elements of the last 3 fold groups.

Further exploratory work and perhaps mining of the Lady Loretta lead-zinc mineralization will test the validity of the above interpretation.

FOLLOW-UP WORK

The author recognizes the fact that he has made at least two very important and unsubstantiated statements:

a) "Diamond drilling has tentatively illustrated that there is a general tendancy for the rock units to thicken to the north". (page 15)

b) The average plunge of the F_2 fold axis of the Mineralized Rock is 30°-030°, as is indicated from diamond drilling exploration . (page 47)

Both statements are related and used in such a way as to make intraformational slumping seem a feasible mechanism by which the barite-chert rock was deformed. Unfortunately the author does not have access to drill hole data that would support these claims. The comments are based on 15 months of familiarity with the area, diamond drilling of it and the interpretation of drilled sections. The above statements should be checked.

Using the ideas of Ross (1971) it may be possible to define the limiting conditions for intraformational slumping to occur and hence demonstrate the likelihood of it occurring within the Lady Loretta sequence.

More structural studies can be made within the area. The fold history as defined above could probably be refined by equally detailed work in similar areas to the north and south. It is felt that the e_1, e_2 and e_3 directions can be approximately defined for the folding that has occurred. After Dietrich (1969), e_1 is perpendicular to cleavage, and the e_2 and e_3 directions can be estimated using; rodding (F_1), elongation of the 'blebs' (F_2), the plots of L_2 (western limb vs eastern limb) (F_3) and the intersection of fanning cleavage. The relationship between folding and faulting within the area could be documented, and is of immediate practical value. More work will have to be done on a larger scale in order to appreciate the regional significance of some of the folds documented. Speculation of the regional significance of the folds observed within the very small area studied (0.45 hectares) is not thought to be warranted.

As this study is the first on the Lady Loretta area (excepting company reports) there is obviously wide scope for further work, especially with respect to sedimentology, mineragraphy, isotope geology (mainly due to the presence of a sulphate and sulphides together) and the genesis of mineralization.

ACKNOWLEDGEMENTS

The field work for this study was carried out while I was employed by Placer Prospecting (Aust.) Pty. Ltd. I would like to express my gratitude to that company for its financial support and to its employees for their co-operation and help in making this report possible. Special thanks to Peter Alcock for many hours of constructive discussion and assistance. Many helpful suggestions were made by Dr. G. Collins, Dr. R. Oliver, Malcolm Bridges, Dr. V. Gostin and Dr. R. Both, for which I thank them. I would also like to thank my colleagues for their willing assistance at all times. There is one person who I am especially indebted to for his constructive criticism, enthusiasm and encouragement throughout the year, my supervisor Dr. M.A. Etheridge. Finally, I would like to thank Janet Brockhurst, Raelee Macdonald and Peter Tucker for their help, without which this thesis may never have been put together.

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MATERIAL SUBMITTED

The following thin and polished thin sections were submitted and accompanied by a hand specimen of each. Of the polished sections submitted, only 394/34 was accompanied by a hand specimen.

Thin Sections :	394/01
	02P
	04
	05
	06N
	08
	10
	11
	13
	17N
	18N
	19N
Polished Thin Sections :	394/25
	27X
	29
Polished Sections :	394/34
	35
	36
	37

All these sections are described in appendix A.

APPENDIX A

Thin Section: 394/01

Location: P68 - 804'

Orientation: 65° to bedding

Rock Type: Laminated, dolomitic carbonaceous siltstone and 'bedded' pyrite associated with three tuffite beds.

Mineralogy: Dolomitic carbonaceous siltstone

Quartz : 20%, grainsize 0.02 mm, angular boundaries, probably includes chert and feldspar grains as well.

Dolomite : 50%, as a matrix with occassional large grains, 0.2mm.

Muscovite : 14%, bimodal, large grains 0.1mm and general v.f.g. material as a matrix.

Carbonaceous Material : 15%, graphite ? wrapped around grains.

Opaques : 1%, pyrite ?, square in cross-section.

<u>'Bedded' pyrite</u>

Pyrite : 80%, commonly square in cross-section, grain size 0.001mm, generally in aggregates.

Matrix : 20%, dolomite, muscovite, quartz crystals (grown perpendicular to bedding and carbonaceous material.)

<u>Tuffites</u> (generally pinkish)

Welded chert (glass), quartz and K-feldspar (Adularia ?) : no cement, grain size 0.02 mm, undulose extinction common, yields a potassium stain, <u>no glass shards</u> observed, minor larger grains of quartz.

Dolomite : larger crystals and aggregates, 0.07 mm, replacing ? the K-feldspar, twinned.

Microstructure: Bedding trace defined; by compositional layering
the elongation direction of the carbonaceous material
the elongation direction of the larger muscovite grains.

- the pyrite is bedded only in the sense that it is confined to a layer that parallels bedding elsewhere.

Thin Section: 394/02P

Location: P73 - 1120'

Orientation: Perpendicular to cleavage plane and bedding.

Rock Type: Poorly bedded dolomitic shale with a dolomitic carbonaceous siltstone bed.

Mineralogy:

Quartz : 15%, associated chert, grain size 0.01 mm, common in dol-carb siltstone bed, centre to 'blebs'.

Dolomite : 40%, as a cement and with muscovite makes up the bulk of the rock.

Muscovite : 40%, preferentially orientated parallel to cleavage, v.f.g, larger grains form beards to 'blebs', minor chlorite.

Carbonaceous Material : 30%, graphite ? virtually restricted to the dol-carb siltstone bed, preferentially orientated.

Opaques : 2%, pyrite ?, largely confined to the dol-carb siltstone bed, grain size 0.01 mm, as a coating to grains.

Microstructure: Cleavage trace - defined by muscovite in the dol-shale where it is a pervasive layering.

- defined by carbonaceous material in the dol-carb siltstone where it is re-distributed from being parallel to the bedding trace and now is the axial plane structure to kinks developed in this pyritic bed.

'Blebs' - ovoid bodies, 0.5 mm diameter, in the dol-shale, quartz or chert centres with chlorite rims and muscovite beards growing perpendicularly to their boundaries and elongated into sigmoidal beards parallel to the cleavage trace, bedding (as defined by carbonaceous material) cuts through these 'blebs'?.

<u>Thin Section:</u> 394/04

Location: P91 - 444'

Orientation: Perpendicular to bedding.

Rock Type: Pyritic dolomite.

Mineralogy: Quartz : 5%, elongate grains 0.5 mm long growing perpendicular pyrite or carbonate contacts, some show undulose extinction and are sigmoidal, small 2V.

Dolomite : 55%, dirty (ankerite ?), as a matrix to the disturbed pyrite.

Opaques : 40%, pyrite ?, irregular and disturbed aggregates, 1mm, grain size 0.1-0.01 mm.

Microstructure: The rock appears to have been a laminated 'bedded' pyrite and dolomite rock, the bedding in which has been completely disrupted by diagenetic movement with associated quartz growth. There is no observable tectonic order to the apparent disturbance.

<u>Thin Section</u>: 394/05

Location: P69 - 1582'

Orientation: Approximately co-planar with the cleavage.

Rock Type: Metamorphosed extrusive lava.

Mineralogy: A whole rock X.R.D. analysis indicated the likely presence of the following minerals:

Chlorite (Thuringite (Ortho))
Ankerite (Ferroan Dolomite)
Quartz (alpha)
Muscovite
Feldspar

The rock is basically a chlorite, quartz rock, with ankerite, muscovite and feldspar only suggested to be present from the X.R.D. output and backed by thin section work.

Microstructure: At least 2 good amygdales are present. Hence the implication that the rock is a regionally metamorphosed extrusive (basic?) lava.

<u>Thin Section</u>: 394/06N

Location: P71 - 1104'

Orientation: Perpendicular to cleavage and bedding.

Rock Type: Carbonaceous dolomitic siltstone or sandstone.

Mineralogy: Quartz : 40%, angular grains not touching, some inclusions and uneven extinction, grain size 0.1 mm.

Feldspars : 10%, grains as for quartz, both K-feldspar and plagioclase observed.

Dolomite : 40%, as a matrix and cement, grain size 0.1 mm.

Muscovite : 2%, associated with more carbonaceous layers, grains 0.1 mm long, minor smaller grains.

Carbonaceous Material : 8%, graphite ?, generally elongated and concentrated into definite horizons.

Accessories : detrital hornblende ? (colourless - green ploechroic)

Microstructure: Bedding trace - defined by carbonaceous material concentrations in beds and elongation of some of this material and of the larger muscovite grains.

Cleavage trace - defined by graphite elongated at an angle to bedding and observed as flames macroscopically and by minor very small mica grains.

- there is no expression of cleavage through the beds that have no carbonaceous material.

Some of the larger mica grains allined parallel to bedding have been bent with the cleavage as a possible axial plane structure. The implication is that these mica grains were formed before the cleavage in the rock and are therefore possibly of detrital or diagenetic origin.

<u>Thin Section:</u>	394/08
Location:	Surface 6390N 1220W
Orientation:	Perpendicular to barite rodding (i.e. true cross-section of a chert fold in the barite-chert rock).
Rock Type:	Barite-chert rock (limonitic).
Mineralogy:	Opaques : blood red limonite, cubic pseudomorphs (after pyrite?) and a general coating on planes of parting (hence traces of it parallel to the barite layering trace), generally associated with the barite not the chert.
	Barite : bimodal, small grains 0.2 - 0.5 mm, make up the bulk of the barite and its layering, larger grains 1 mm by 2 mm, associated with veins in and around the chert material, undulose extinction.

Chert : drussy due to some limonite impregnation, irregular but long masses.

Microstructure: Bedding trace - defined compositionally, two compositions (chert and barite veins and barite and opaques)

- folded isoclinally with a barite + opaques layering trace as the axial plane structure.

Cleavage trace - equivalent to layering trace and is the axial plane structure to the chert fold

- defined by a limonite coating on parting surfaces parallel to the cleavage or barite layering.

The thickness of the chert is irregular due to a necking tendency during folding. The barite veins through the chert are approximately perpendicular to bedding.

Thin Section: 394/10

Location: P103 - 811'

Orientation: Perpendicular to cleavage and bedding.

Rock Type: Poorly bedded, well cleaved, dolomitic micaceous siltstone.

Mineralogy:

Quartz : 40%, some chert and feldspar grains included, grains size 0.05 mm, undulose extinction, angular, grains generally not touching.

Dolomite : 13%, dirty (ferroan dolomite?) matrix with muscovite.

Muscovite : 40%, bimodal, long thin grains and short fat grains.

Carbonaceous Material : 5%, graphite?

Opaques : 2% pyrite?, disseminated.

Microstructure: (Fig. 12, 13)

Bedding trace - poorly defined by carbonaceous material concentration in a layer that has been disturbed by some slippage parallel to the cleavage trace.

- the short and fat muscovite grains are parallel to bedding.

Cleavage trace - well defined by the grain elongation of carbonaceous material and better still by the grain elongation of long thin muscovite grains, gives rise to a pervasive cleavage.

'Blebs': The 'blebs' observable in hand specimen are odd concentrations of quartz and dolomite.

Thin Section: 394/11

Location: P84 - 900'

Orientation: Perpendicular to bedding and cleavage.

Rock type: Calcareous arkose with a vein of K-feldspar + quartz + dolomite.

Mineralogy: Quartz : 10%, ovoid grains, grain size 0.08mm, sub rounded to angular, undulose extinction.

K-feldspar: 25%, adularia?, drussy orange-yellow colour, grains as for quartz.

Chert : 30%, dirty grains as for quartz.

Dolomite : 15%, generally as a matrix with opaques and muscovite.

Muscovite : 18%, small grains, 0.02 mm, and as a matrix, rare larger grains.

Carbonaceous Material : 1% graphite ? elongated blades.

Opaques : 1%, pyrite ?, grain size 0.01 mm

Microstructure: Bedding trace - defined by elongation of carbonaceous material by the major axes of the quartz, K-feldspar and chert grains (imbricate structure?) and by the elongation of rare large muscovite grains.

Cleavage trace - very poor expression by small muscovite grains only.

Vein: Composed of quartz : 50%, undulose extinction

K-feldspar : 30%, yellow-orange colour (adularia)

Dolomite : 20%, coarse grained

which are all coarse grained 0.5 mm to 3 mm and elongated perpendicular to the vein walls, sometimes bent and sigmoidal. The vein-arkose contacts follow the arkose grain boundaries.

Thin Section: 394/13

Location: P98 - 778'

Orientation: Parallel to cleavage and perpendicular to bedding.

Rock Type: Oxidised (rusted) micaceous carbonaceous sandstone.

Mineralogy: Quartz : 50%, it is likely that 10% of this is really feldspar, grain size 0.1 to 0.05 mm, undulose extinction, sericitized edges. (this is a very common occurrence in these rocks).

Muscovite : 20%, bimodal, large grains of long dimension 0.2 mm, small grains (sericite associated with quartz grains) 0.02 mm.

Carbonaceous material : 15%, graphite? elongated and wrapped around detrital grains.

Opaques : 15%, Fe oxides, some pseudomorphous after pyrite and hence implying that the rusting is not necessarily an indication of oxidizing conditions during sedimentation.

Microstructure: The section was cut such that the cleavage and bedding traces should be parallel. No second cleavage was observed.

<u>Thin Section</u>: 394/17N

Location: P74 - 982'

Orientation: Perpendicular to bedding and at about 60° to cleavage.

Rock Type: Pyritic argillaceous dolomite with a carbonaceous siltstone bed and 'blebs'.

Mineralogy: A whole rock X.R.D. analysis indicated the likely presence of the following minerals:

Muscovite (K variety)
Paragonite (Na variety)
Quartz (alpha)
Ankerite (Ferroan Dolomite)
Chlorite
Pyrite
Graphite - possible
Hydrazinium Zinc Sulphate
$(N_2H_5)_2 Zn(SO_4)_2$ - possible?

In both rocks, 394/05 and 394/17, a d-spacing of 4.596 Å and 4.5918 Å and intensities of 4.2 and 5.7 respectively were found which could not be identified with any other mineral excepting hydrazinium zinc sulphate. It is thought that such a mineral might be possible in 394/17 which is associated with zinc mineralization and carbonaceous material, but <u>not</u> in 394/05 which is a metamorphosed extrusive lava.

Quartz : 5%, undulose extinction, variable grain size 0.1 mm to 0.02 mm, irregular boundaries, mainly associated with the carbonaceous siltstone bed.

Dolomite : 50%, (ferroan dolomite or ankarite), grain size 0.1 mm in 'blebs', generally fine grained 0.02 mm.

Muscovite : 30%, grain size 0.02 mm, paragonite included.

Chlorite : 1%, as rims around carbonate blebs.

Carbonaceous Material : 5%, graphite?, elongated, wraps around grains.

Opaques : 9%, pyrite, cubic outlines to grains, 0.005 mm diam, disseminated and in aggregates.

Microstructure: Bedding trace - defined by

a) change in mineral assemblage (between argillaceous dolomite and carbonaceous siltstone).

b) mineral elongation preferred orientation (of muscovite and carbonaceous material), the muscovite grains elongated parallel to the bedding trace are larger than those elongated parallel to the cleavage trace.

Cleavage trace - defined or indicated by

a) mineral elongation preferred orientation (of muscovite paragonite and carbonaceous material).

b) 'bleb' elongation

c) mica beards around the 'blebs' and small pyrite aggregates are also elongated parallel to the cleavage trace.

- the cleavage trace is refracted towards the normal on passing through the carbonaceous siltstone.

'Blebs': (Fig.16) These 'blebs' are dolomite concentrations with chlorite rims, ovoid in cross-section, the beards developed at their ends are sigmoidal, carbonaceous bedding traces are refracted? on passing through them, pyrite is grown in and through them (or the 'bleb' around the pyrite). There are also some rare pyrite aggregate blebs (framboidal pyrite?), of unknown origin or development.

Thin Section: 394/18N

Location: P84 - 822'

Orientation: Perpendicular to both cleavage and bedding.

Rock Type: Laminated carbonaceous dolomite with cleavage accentuated flame structures.

Mineralogy: Quartz : 5%, irregular boundaries, undulose extinction, grain size 0.03 mm.

Dolomite; 80%, grain size 0.02 mm

Muscovite : 10%, disseminated and associated with the more carbonaceous beds.

Carbonaceous Material : 5%, graphite?, elongated.

Accessory : pyrite.

Microstructure: Bedding trace - defined by changes in mineral assemblages (mainly carbonaceous material)

- and elongation of carbonaceous material and muscovite.

Cleavage trace - defined by the elongation of carbonaceous material and muscovite (where the bulk rock composition is such that it was able to form).

- locally controlled to some extent by the flame structures that were originally developed in the rock, gives an irregular and <u>not</u> a pervasive fabric. (Fig. 15)

Veins: Lined by carbonaceous material and filled with dolomite and quartz.

Thin Section:	394/19N
Location:	P98 - 435'
Orientation:	Perpendicular to both bedding and cleavage.
Rock Type:	Silty dolomitic carbonaceous shale with dolomitic siltstone shale and carbonaceous siltstone slump material.
Mineralogy:	Quartz : 30%, grain size 0.04 mm, angular, undulose extinction, about 50% of this material is very likely to be K-feldspar and chert.
	Dolomite : 25%, generally as a matrix, concentrated in slumped material.
	Muscovite : 35%, grain size 0.02 mm, minor associated chlorite.
	Carbonaceous Material : 9%, graphite?, elongated, wraps around grains.
	Opaques : 1%, pyrite?, cubic outlines, grain size 0.002 mm.
Microstructure:	Bedding trace - very poorly defined, some carbonaceous material parallel to this direction and also some

muscovite roughly elongated parallel to the bedding trace.

Cleavage trace - defined by elongation (preferred orientation) of muscovite and carbonaceous material parallel to the cleavage trace.

- strongly developed to the extent of deforming the slumps which now show a rough elongation parallel to the cleavage trace.

<u>Polished Thin Section:</u> 394/24X

Location: P103 - 796'

Orientation: Perpendicular to both cleavage and bedding.

Rock Type: Kinked dirty dolomite and 'bedded' pyrite with cross-crystallized quartz.

Mineralogy: Quartz : elongate grains, 2mm to 0.1 mm long, indistinct grain boundaries with other quartz and dolomite grains, undulose extinction, some grains bent.

Dolomite : dirty (ferroan dolomite?) as a matrix to the cross-crystallized quartz, as a sediment and very fine grained.

Accessary Gangue : feldspar and muscovite.

Carbonaceous Material : as coating to grains, graphite?

Pyrite : grain size 0.001 mm to 0.002 mm aggregates are roughly allined as an axial plane structure to the kinks (as shown by bedding)? generally disseminated throughout the sediment.

Sphalerite : accessary grains only, associated with the pyrite and cross-crystallized quartz.

Microstructure: Bedding trace - defined by layers of different mineral assemblages.

- folded by kinking.

Cleavage trace - defined by elongation direction of carbonaceous material which is an axial plane structure to the kinks (also pyrite aggregates?).

- the cross-crystallized quartz only appears to be elongated parallel to the cleavage trace, thought to be of diagenetic origin and later kinked with the bedding.

Polished Thin Section: 394/25

Location: P104 - 111'

Orientation: Perpendicular to layering.

Rock Type: Barite, chert, sphalerite, pyrite rock.

Mineralogy: A whole rock X.R.D. analysis indicated the presence of the following minerals.

Pyrite
Sphalerite
Barite
Quartz
Galena - possible
Calcium Manganese Oxide Hydrate - possible?

The latter mineral is identified with d-spacings of 2.117, 2.111 and 7.162 Å and intensities of 16.5, 14.1 and 2.3 respectively. The same d-spacings and order of intensities were also observed in an X.R.D. whole rock analysis of a surface barite specimen. No odd mineral was observed in thin section work.

Quartz : 15%, includes chert fragments, as grains generally associated with the barite, grain size 0.2mm.

Barite : 40%, as a general matrix, undulose extinction, grain size 0.2 mm, some barite aggregates show extinction crosses?, only impurity in sphalerite aggregates.

Sphalerite : 40%, aggregates are poikolitic textured by barite inclusions, orange-brown colour, minor associated pyrite and galena.

Pyrite : 5%, bimodal, 0.01 mm grains in matrix and sphalerite, large grains 2 mm to 0.5 mm, poikolitic textured, some being replaced? by sphalerite, partly formed cubic crystals are common (atoll texture)

Accessaries : galena and chalcopyrite.

Microstructure: Sphalerite appears to be replacing pyrite and both appear to have replaced gangue. Barite layering trace is defined by different mineral assemblages (sphalerite with barite and barite with sphalerite and quartz) and also by a tendancy for barite and sphalerite grains to be elongated parallel to this direction. There is also a tendancy for some grains to be elongated at a slight angle to the foliation trace? (Fig. 5) Barite inclusions in sphalerite and pyrite aggregates have a tendancy to form triangular boundaries.

<u>Polished Thin Section:</u> 394/27X

Location: P63A - 1552'

Orientation: Perpendicular to fold axis.

Rock Type: Folded banded ('bedded') sulphide mineralization with associated cross-crystallized quartz and carbonaceous, dolomitic interbeds.

Mineralogy: Quartz : 3 modes of occurrence, generally undulose extinction.

a) as detrital grains 0.05 mm in sediment

b) as elongated grains perpendicular to bedding, long dimension 1 mm, generally bent sigmoidally, indefinite grain boundaries, cross-crystallized quartz.

c) euhedral grains associated with quartz as in b).

Dolomite : dirty (ferroan dolomite), as a matrix with quartz, muscovite and carbonaceous material in sediment, vein material, associated with quartz as in b).

Muscovite : concentrated in the more carbonaceous rich sediment and always elongated parallel to the bedding trace.

Pyrite : range of grain size 0.01 mm to 0.001 mm, euhedral, separate grains, crystallographic outlines common.

Sphalerite : granular bands parallel to bedding trace with minor pyrite, galena and carbonaceous material.

Carbonaceous Material : graphite?, general distribution throughout the rock.

Accessaries : chalcopyrite, hematite.

Microstructure: Bedding trace is defined by different mineral assemblages, mainly 'bedded' pyrite, 'bedded' sphalerite and galena and beds of gangue material. Sphalerite and galena appear to be finer grained and not as common in fold hinges, in comparison to limb areas of the same bed. Galena and sphalerite are associated with the cross-crystallized quartz, as for b) above.
Sphalerite and galena grain aggregates appear to be elongated parallel to the axial plane of the fold and in places intrude the gangue bed, above and below.

Polished Thin Section: 394/29

Location: P73 - 1095'

Orientation: Perpendicular to both bedding and cleavage.

Rock Type: Laminated 'bedded' pyrite and carbonaceous silty dolomite.

Mineralogy: 'Bedded' pyrite.

Quartz : crystals growing in gaps between pyrite aggregate layers.

Dolomite : as a general matrix mineral with quartz.

Carbonaceous Material :

Pyrite : 60%, grain size 0.01 mm to 0.003 mm, aggregate size up to 0.2 mm, generally only show a poor development of crystallographic faces.

Carbonaceous silty dolomite

Quartz : 30%, minor associated K-feldspar

Dolomite : 60%, dirty (ferroan dolomite)

Muscovite : 5%

Carbonaceous Material : Graphite ?

Sulphides: pyrite (disseminated and some aggregates), chalcopyrite and sphalerite, there are about equal amounts of sphalerite and pyrite.

A vein of a 'black mineral' in the hand specimen was identified as graphite using X.R.D. methods.

Microstructure: (Fig. 14)

Bedding trace is defined by different mineral assemblages (mainly gangue and pyrite).

Cleavage trace is defined by:

a) elongation of carbonaceous material

b) the quartz crystals in the 'bedded' pyrite are elongated parallel to the cleavage direction.

c) the layers of pyrite aggregates are broken in places and filled with small grains of pyrite, this is seen in the hand specimen as a cleavage trace defined by 'remobilized' pyrite.

d) elongation of pyrite aggregates in the carbonaceous silty dolomite.

e) accentuation of flame structures or load casts of pyrite into host rock.

Kinks have been formed by the bedding with the cleavage trace as the axial plane structure and it is likely that b), c), and e) above are genetically related to this kinking.

Polished Section:	394/34
Location:	P101 - 1182'
Orientation:	Perpendicular to layering (supposedly bedding).
Rock Type:	Fine grained sulphide mineralization.
Mineralogy:	Quartz : 12%, crystals, minor detrital grains.
	Dolomite : 6%, sphalerite, galena and pyrite inclusions (and also in the quartz.)
	Muscovite : 2%, idiomorphic, associated with carbonaceous material.
	Carbonaceous Material : 2%, thought not to be strictly graphite, inclusions in sulphides (especially sphalerite).
	Pyrite : 23%, bimodal, grain sizes 0.02mm (idiomorphic and associated with other sulphides), 0.001 mm to 0.002 mm (occassionally idiomorphic, atoll textured, associated with carbonaceous material).

Sphalerite : 48%, suggested grain size of 0.01 mm, numerous inclusions (especially galena), not evenly distributed throughout the rock.

Galena : 7%, range of grain sizes, inclusions in sphalerite 0.001 mm to aggregates 0.5 mm, generally free of inclusions.

Accessary Minerals : Chalcopyrite (inclusions in the sphalerite, 0.002 mm)
Arsenopyrite (inclusions in the sphalerite, 0.002 mm).
Bornite (trace)
Hematite (elongate grains, speccular variety, associated with the gangue minerals).

Microstructure: Inclusion grain boundary relationships in the sphalerite,
pyrite - good cubic crystals
arsenopyrite - good crystal form
chalcopyrite - round grains
galena - cuspate grain boundaries

these relationships suggest grain boundary equilibrium for the sulphides within the sphalerite.
Muscovite and Carbonaceous material grains are elongated parallel to each other but what this trace defines is not known.

Also the layering observed in hand specimen is not observable microscopically.
Galena commonly fills veins and fractures with carbonaceous material. In hand specimen the galena appears to be 'remobilized' in two directions (parallel to cleavages?) but the galena 'remobilization' is confusing when studied under magnification.

<u>Polished Section</u>:	394/35
Location:	Surface 6700N 500W
Orientation:	Perpendicular to cleavage and bedding.
Rock Type:	Siliceous honeycombed rock.
Description:	No cleavage or bedding traces are identifiable microscopically. The rock is generally silicified. The limonite nodules are concentrically zoned by different compositions of limonite (hematite, goethite, jarosite?) which can be seen in hand specimen by changes in colour. The boundary of limonite nodules are irregular and defined by the limits of migration of limonite into the host rock.

Polished Section: 394/36

Location: Surface 7040N 1750W

Orientation: Perpendicular to both bedding and cleavage.

Rock Type: Mineralized rock.

Description: This rock is thought to be equivalent to laminated sulphide mineralization and sediments in fresh rock on the basis of the common association of cross-crystallized quartz with mineralized sediment.
This rock has undergone complete silicification excepting minor hematite grains with the preservation of the texture of the original sediment.

Polished Section: 394/37

Location: Surface 5990N 1500W

Orientation: Perpendicular to bedding.

Rock Type: Lower limonitic shales and siltstones.

Description:

Both quartz and mica grains are still observable despite the high degree of ferrugination the rock has undergone, they have not been replaced by limonite.

The limonite (hematite, goethite, jarosite?) has replaced the matrix of the rock and now is itself the matrix of the rock. However, there are two directions in which the limonite is more continuous than others, (appears to have preserved original microstructures in the rock - observable under high magnification). Hence limonite fabrics:

1) parallel to the bedding trace

2) parallel to the cleavage trace

APPENDIX B

Lower Siltstone

This unit is characterized by load casts and cross-beds in carbonaceous dolomitic siltstones and some sandstones (394/06, 394/11). Laminated rusted micaceous carbonaceous siltstones (394/13), potassium rich sandstones and carbonaceous dolomites (394/18) are also common, along with an average 'bedded' pyrite content of 15%. Some of the sediments show a poorly developed cyclic relationship of siltstone or sandstone, shale and laminated dolomitic carbonaceous siltstone or 'bedded' pyrite. The unit has a minimum thickness of 200 m. Its upper contact is defined on the basis of the amount of 'bedded' pyrite present and is generally gradational over an interval of about 5 m.

Mineralization

This unit is discussed separately in Appendix C.

Lower Carbonaceous Shale

Laminated dolomitic carbonaceous shales (394/01), pyritic dolomitic shales (394/02, 394/17) and variable amounts of 'bedded' pyrite (5% to 40%) are characteristic of this unit. Its thickness is extremely variable from about 20 m to 80 m., part of which is thought to be due to its poorly defined contacts. The base of the unit is defined as being at the bottom of two tuffites, each about

1 cm thick. But these are not always present and low-grade lead-zinc mineralization can occur both above and below these tuffites. The top of the unit is even more poorly defined as being a level at which cyclic sedimentation ceases. There is usually a gradational sequence of poorly defined cycles to the cyclic unit above. It is estimated that the maximum error in defining this unit could be as large as 30 m.

Cyclic Beds

This unit is characterized by the cyclic sedimentation of:

dolomitic carbonaceous siltstone and or 'bedded' pyrite (394/01)

dolomitic shales (394/17, 394/02)

dolomitic silty shale with dolomitic siltstone slump material (394/10)

dolomitic argillaceous siltstones and sandstones with abundent slump material of all lithologies, including 'bedded' pyrite and K-feldspar (394/19, 394/11)

It is thought that the incomplete development of a cycle is a result of either erosion during slumping or another slump before the sedimentation cycle has reached the 'bedded' pyrite stage. As described above, the base of this unit is only poorly defined. The top of the unit is well defined and is the base of a distinctive pyritic dolomite bed (394/04). This marker has a maximum thickness of about 4 m, but is unfortunately discontinously developed. The cyclic unit varies in thickness from 30 m to 90 m. The average 'bedded' pyrite content of the unit is 5%, excepting for about the top 7 m which have a 'bedded' pyrite content of greater than 40%.

Upper Carbonaceous Shale

Shales and carbonaceous dolomitic shales (394/02) are typical of this unit with minor dolomitic siltstones, dolomitic carbonaceous siltstones and 'bedded' pyrite (5% - 10%). 'Blebs' (Fig. 16, 394/17, 394/02, 394/10), although commonly developed in this unit are not restricted to it. This unit has a minimum thickness of about 150 m.

APPENDIX C

'Bedded' Lead-Zinc Mineralization

This mineralization is confined between the base of the Lower Carbonaceous Shale unit and either the barite-chert rock or massive 'bedded' pyrite below. It is composed primarily of almost monomineralic beds of pyrite, sphalerite and galena, laminated with dolomitic micaceous carbonaceous siltstones and characterized by layers of cross-crystallized quartz (394/24, Fig 17).

As evidence supporting the sedimentary or at least early diagenetic deposition of the mineralization, a limited number of slumps made up of both detrital sediment and 'bedded' mineralization have been observed within the lead-zinc mineralization. The grade of the mineralization is dependent on the amount of associated 'bedded' pyrite and detrital sediment occurring with it. In general the grade of the mineralization increases to a maximum at the base of the unit. Unlike the host rocks the lead-zinc mineralization is highly contorted by small scale folding (394/27).

A total of 9 polished thin-sections and 1 polished section were studied. The opaque minerals identified and their microstructures are summarized below.

Minerals Identified:

Major - Pyrite
Sphalerite (colour - deep reddish black)

Galena
Carbonaceous Material (graphite?)

Minor - Chalcopyrite
Hematite (variety - specular)
Arsenopyrite

Rare - Marcasite
Chalcocite
Bornite

The mineralization is typically fine grained (0.001 mm to 0.01 mm for galena, sphalerite, pyrite, chalcopyrite and arsenopyrite) with the grain aggregates being an order of magnitude larger (0.01 mm to 0.1 mm for galena and sphalerite). Pyrite only rarely forms aggregates and its grains are generally twice the size in a bed of sphalerite than in 'bedded' pyrite. The carbonaceous material is typically flaky. The sphalerite aggregates and beds are full of microscopic inclusions of all the other minerals present. This also applies to galena aggregates, but to a lesser extent. The commonly observed sphalerite/other sulphide grain boundary relationships are:

arsenopyrite - generally good rectangular crystal outlines developed

pyrite - an average of at least three good cubic crystal faces developed

chalcopyrite - round grains

galena - cuspate grain boundaries

These grain boundary relationships suggest an attainment of grain boundary equilibrium of these sulphides with sphalerite. Galena and to some extent chalcopyrite are more common than sphalerite in the relatively minor number of veins present. Also, galena, chalcopyrite hematite and dolomite are commonly associated with cross-crystallized quartz

Barite-Chert Rock

This unit is generally confined between the Lower Carbonaceous Shales unit or lead-zinc mineralization above and the massive 'bedded' pyrite below. It is a homogeneous barite, chert, pyrite, sphalerite rock with minor amounts of galena and the occasional development of fine grained massive pyrite and chert lenses.

A total of 3 polished-thin sections and 1 polished section were studied. The opaque minerals identified and their microstructures are summarized below.

Minerals Identified:

Major - Sphalerite (colour - amber, orange)
Minor - Pyrite
Galena
Carbonaceous Material (Graphite?)
Rare - Chalcopyrite

The gangue minerals associated with these rocks are barite, crystalline quartz, chert and minor dolomite (394/25). No fluorite was observed. Sphalerite, pyrite, barite plus quartz and chert form lensoid aggregates and hence define the layering. The sphalerite and pyrite aggregates have poikolitic textures caused by abundent (up to 40% of the aggregate) barite inclusions. Generally the grain size is 0.01 mm with occasional larger pyrite grains (1 mm) and these grains are all elongated with their long axis parallel to the layering trace (Fig.5). Galena is irregularly dispersed throughout the rock.

Massive 'Bedded' Pyrite

This mineralization is invariably the basal unit of the Mineralized Rocks, with or without lead-zinc mineralization or the barite-chert rock developed above it. The rock is essentially composed of alternating beds of laminated dolomitic carbonaceous siltstones, shales and dolomites with laminated 'bedded' pyrite (Fig. 14).

Four (4) polished-thin sections and 2 polished sections were studied. The opaque minerals identified and their microstructures are summarized below.

Minerals Identified:

Major - Pyrite
Minor - Carbonaceous Material (Graphite?)
Rare - Sphalerite
Galena

The bedding in the 'bedded' pyrite is defined by a sharp change in the concentration of pyrite grains from one band to another (90% pyrite to 30% pyrite). The grain size of pyrite ranges from 0.001 mm to 0.01 mm. Generally the smaller grains are more idiomorphic and do not appear to have a coating of carbonaceous material around them, as is the case for the larger grains. The beds with the higher pyrite content are often boudinaged perpendicularly to bedding and kinked, with or without the associated development of cross-crystallized quartz (394/24, Fig 14 and 17). Only disseminated sulphides occur in the associated clastic sediments but there are equal amounts of pyrite and sphalerite present. It is to be noted that no framboidal textures were observed and that the pyrite grains could be generally described as having atoll-like textures (Croxford & Jephcott, 1972, page 8.).

APPENDIX D

Banded Limonitic Shales and Cherts

This lithology is characterized by occasional beds of chert about 1-2 cm thick and is generally completely impregnated with limonite. Structures resembling stromatolites occur at 7100N 1950W. These rocks lie to the north of the Carlton Fault (Plate 2) and do not belong to the sequence hosting the lead-zinc mineralization.

Upper Limonitic Shales and Siltstones (Fig. 7, 8, 11)

These rocks occupy the core of a synclinal structure. They are typically cleaved and blocky with limonitic bands indicating bedding. Parting occurs along planes parallel to bedding and jointing, not cleavage. Their impregnation with limonite increases with topographic height. Within the area mapped, the main areas of outcrop are on the tops of flat topped hills which were once part of an old land surface (Mesozoic ?).

Siliceous Honeycombed Rock (394/35, Fig 9)

This lithology is similar to and associated with the rock type mapped as Silicified Shales and Siltstones, but it is characteristically different from it in that it contains holes of about 5 mm diameter. These holes vary in their density of development (5% to 50%) and can also be either circular or cubic with infills of gypsum?, limonite or are completely empty. The cubic holes are empty and not limonitic. This rock type is capable of transgressing bedding and this is thought to be due to the fact that the holes are a secondary development in the rock and are not equivalent to a primary feature.

Silicified Shales and Siltstones (Fig. 6, 10)

These rocks include all those lithologies between a true secondary chert (commonly not limonitic) and a siliceous limonitic shale or siltstone. The general characteristic of this lithology is that the rock fractures through grains.

Hematite

The hematite is generally siliceous in part, massive and fine-grained. Bedding is rarely preserved.

Barite-Chert Rock (394/08, Fig. 2, 3, 4)

This rock type developes a typical weathering profile caused by quartz and chert rich layers and aggregates standing out in relief. It is typically grey and heavy. Layering is well developed and lensoid masses and tight isoclinal folds of chert (Fig 2) are common. Hematite cappings are typically associated with it.

Silicified Breccia

This lithology has the appearance of a silicified brecciated Barite-Chert rock.

Chert

As mentioned above, this lithology is the end member of the Silicified Shales and Siltstones and is a secondary chert. It is typically massive and has a concoidal fracture.

Mineralized Rock (394/36)

This rock type varies from a completely silicified rock to a hematitic jasper and is characterized by showing relict cross-crystallized quartz associated with kinked or contorted bedding.

Massive Siliceous Limonite

Some of the lithologies mapped as being of this rock type have caked crusts, nodules and collumnar limonite which are supposedly characteristic of being derived from almost massive pyrite (Blanchard, 1968, chapter 18). The rock could also be called a jasper. The limonite is a chocolate brown colour.

Cellular Limonite

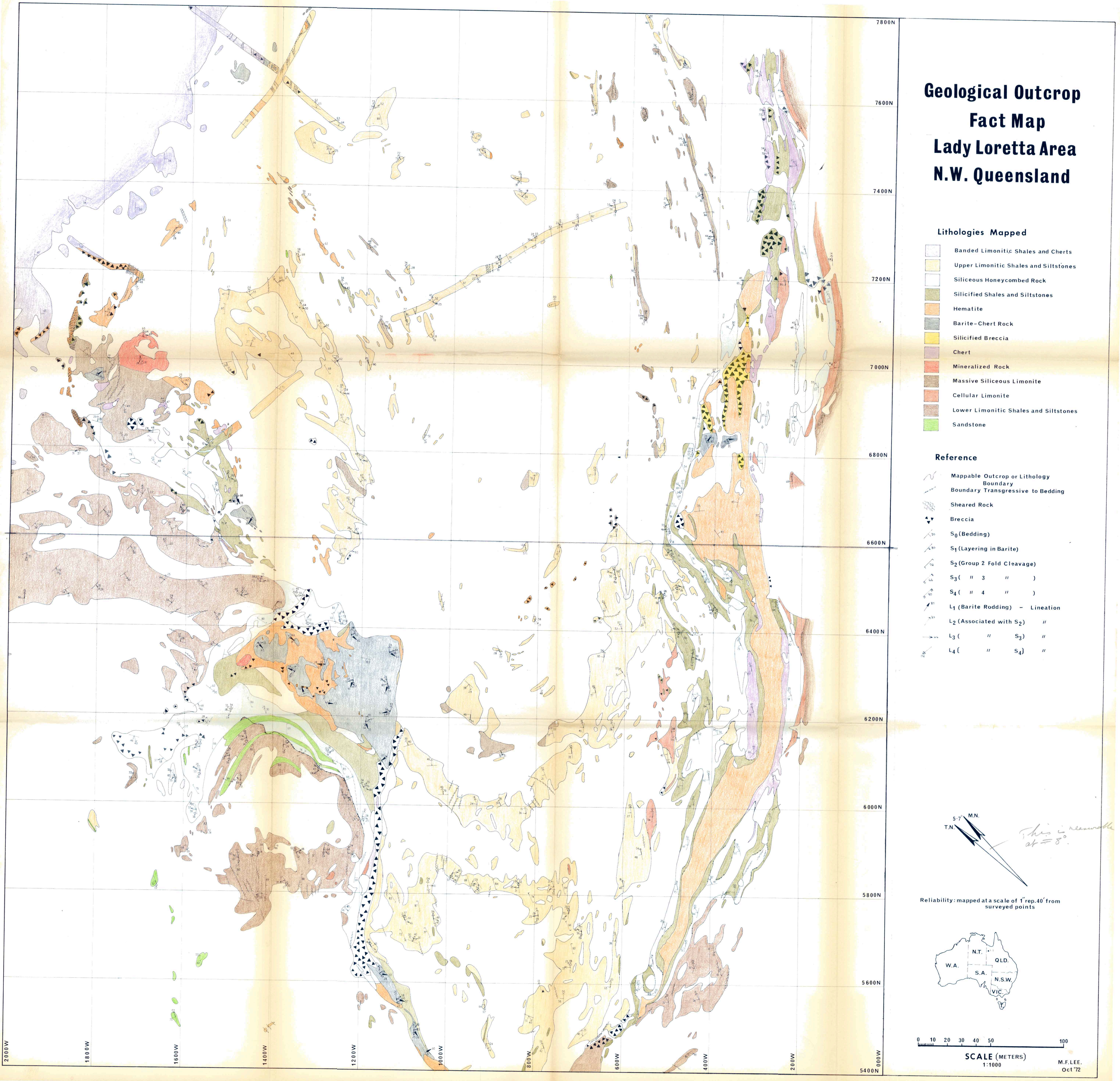
These rocks are porous, siliceous and are also supposedly characteristic of weathered pyrite. The colour of the limonite varies from a fawny brown for the more earthy outcrops, to deep red brown for the more massive occurrences.

Lower Limonitic Shales and Siltstones (394/37)

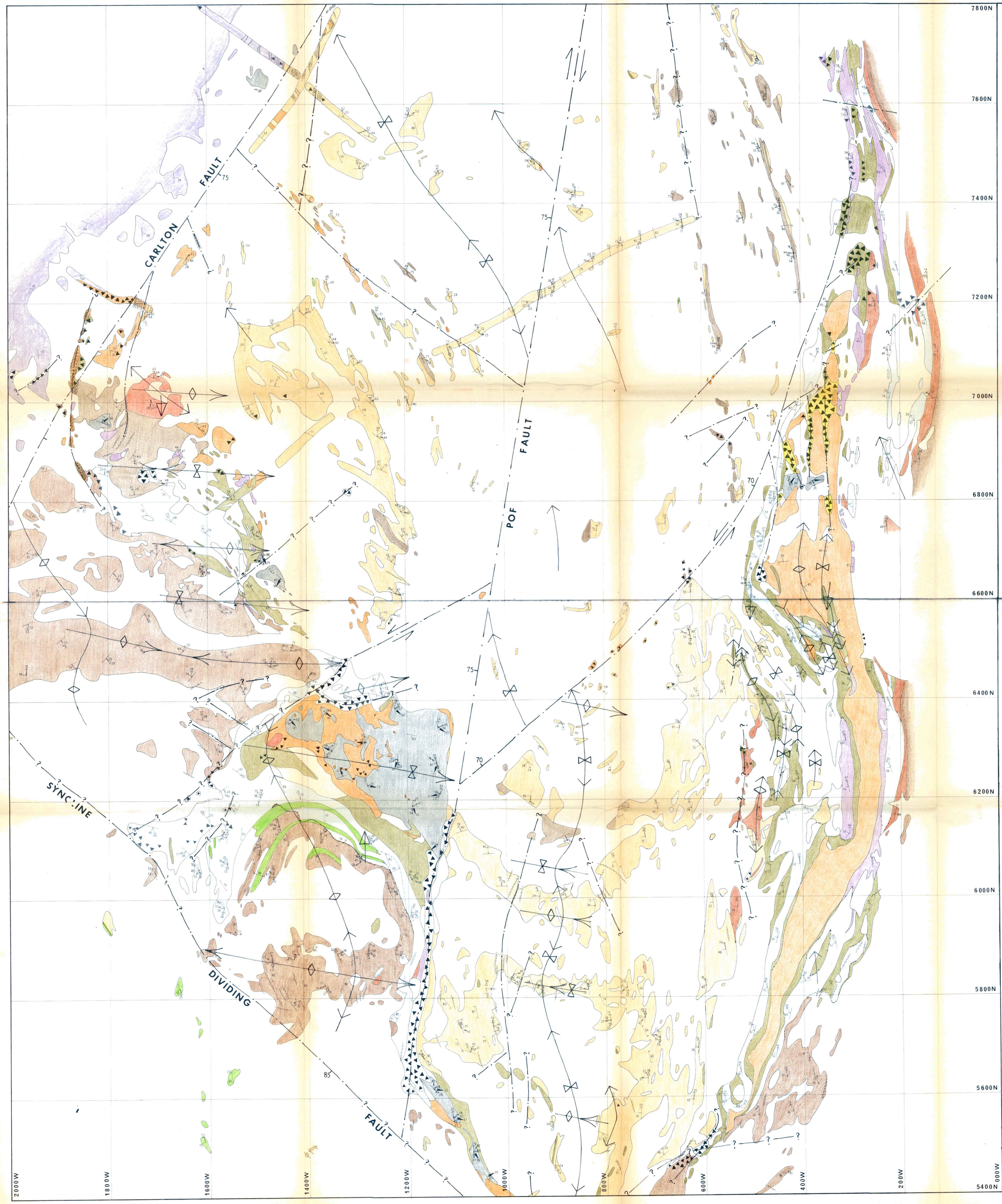
This lithology is very similar to the more limonitic rocks mapped as Upper Limonitic Shales and Siltstones but in comparison is generally more silty and limonitic. It is characterized by the presence of cross-bedded siltstones.

Sandstone

Two different sandstones were mapped. The one around 6100N 1400W is a coarser grained sediment associated with the Lower Limonitic Shales and Siltstones. The other around 5700N 1600W, is a poorly bedded micaceous sandstone and is separated from the former by a fault. This sandstone is stratigraphically above the rocks hosting the lead-zinc mineralization.



Geological Outcrop
Fact Map
Lady Loretta Area
N.W. Queensland
Lithologies Mapped
Banded Limonitic Shales and Cherts
Upper Limonitic Shales and Siltstones
Siliceous Honeycombed Rock
Silicified Shales and Siltstones
Hematite
Barite–Chert Rock
Silicified Breccia
Chert
Mineralized Rock
Massive Siliceous Limonite
Cellular Limonite
Lower Limonitic Shales and Siltstones
Sandstone
Reference
Mappable Outcrop or Lithology Boundary
Boundary Transgressive to Bedding
Sheared Rock
Breccia
S_0 (Bedding)
S_1 (Layering in Barite)
S_2 (Group 2 Fold Cleavage)
S_3 (" 3 ")
S_4 (" 4 ")
L_1 (Barite Rodding) – Lineation
L_2 (Associated with S_2) "
L_3 (" S_3) "
L_4 (" S_4) "
5·7°
M.N.
T.N.
Reliability: mapped at a scale of 1" rep. 40' from surveyed points
N.T.
QLD.
W.A.
S.A.
N.S.W.
VIC.
0 10 20 30 40 50 100
SCALE (METERS)
1:1000
M.F.LEE.
Oct '72
7800N
7600N
7400N
7200N
7000N
6800N
6600N
6400N
6200N
6000N
5800N
5600N
5400N
2000W
1800W
1600W
1400W
1200W
1000W
800W
600W
400W
200W
000W



Interpretted Geological Structure Lady Loretta Area N.W. Queensland

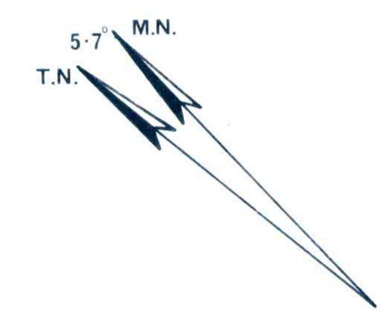
Lithologies Mapped

- Banded Limonitic Shales and Cherts
- Upper Limonitic Shales and Siltstones
- Siliceous Honeycombed Rock
- Silicified Shales and Siltstones
- Hematite
- Barite-Chert Rock
- Silicified Breccia
- Chert
- Mineralized Rock
- Massive Siliceous Limonite
- Cellular Limonite
- Lower Limonitic Shales and Siltstones
- Sandstone

Reference

- Mappable Outcrop or Lithology Boundary
- Boundary Transgressive to Bedding
- Sheared Rock
- Breccia
- S_0 (Bedding)
- S_1 (Layering in Barite)
- S_2 (Group 2 Fold Cleavage)
- S_3 (" 3 ")
- S_4 (" 4 ")
- L_1 (Barite Rodding) – Lineation
- L_2 (Associated with S_2) "
- L_3 (" S_3) "
- L_4 (" S_4) "
- Fault: position accurate; dip and sense of displacement shown
- Fault: position or existance doutful
- Syncline Axial Trace
- Anticline Axial Trace

(arrow shows plunge direction and fold group:
Group 2 Folds
" 3 "
" 4 ")



Reliability: mapped at a scale of 1" rep. 40' from surveyed points

0 10 20 30 40 50 100

SCALE (METERS)
1:1000

M.F. LEE.
Oct '72