Economic Geology, v. 62, pp. 757-772

ECONOMIC GEOLOGY

AND THE

BULLETIN OF THE SOCIETY OF ECONOMIC GEOLOGISTS

VOL. 62 SEPTEMBER–OCTOBER 1967 NO. 6

FOSSIL GOSSANS (?) AT MT. LYELL, TASMANIA

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ABSTRACT

The orebodies at Mt. Lyell consist of pyrite and copper sulfide lenses in deformed, chloritized and sericitized volcanic rocks of Cambrian age. The volcanic rocks are overlain unconformably by Ordovician terrestrial conglomerates that contain basal lenses of hematite overlying sulfide ores. The field relationships, mineralogy, and chemistry of the hematite bodies suggest they were gossans or limonitic screes developed during Ordovician weathering of the adjacent sulfides.

INTRODUCTION

THE Mt. Lyell mining field was opened by prospectors who believed that alluvial gold was coming from a prominent outcrop of hematite known as the Iron Blow. The origin of this hematite aroused much discussion until early this century when the iron ore was removed during the working of the adjacent pyrite mass by the Mt. Lyell Mining and Railway Company. Another mass of hematite, still in situ, was found later during the working of the North Lyell bornite-chalcopyrite-pyrite ores.

Previous writers have expressed widely divergent opinions concerning the origin of the hematites, but I have concluded from a re-examination of the area that the earliest workers were right in suggesting that the hematite masses are Ordovician gossans. Because fossil gossans of such age are rare, a fairly full account of these examples is given in this paper.

THE GEOLOGICAL SETTING

The Mt. Lyell copper ores are worked along a mile-long strip of the West Coast Range in Western Tasmania, near Queenstown (Fig. 1). Table 1

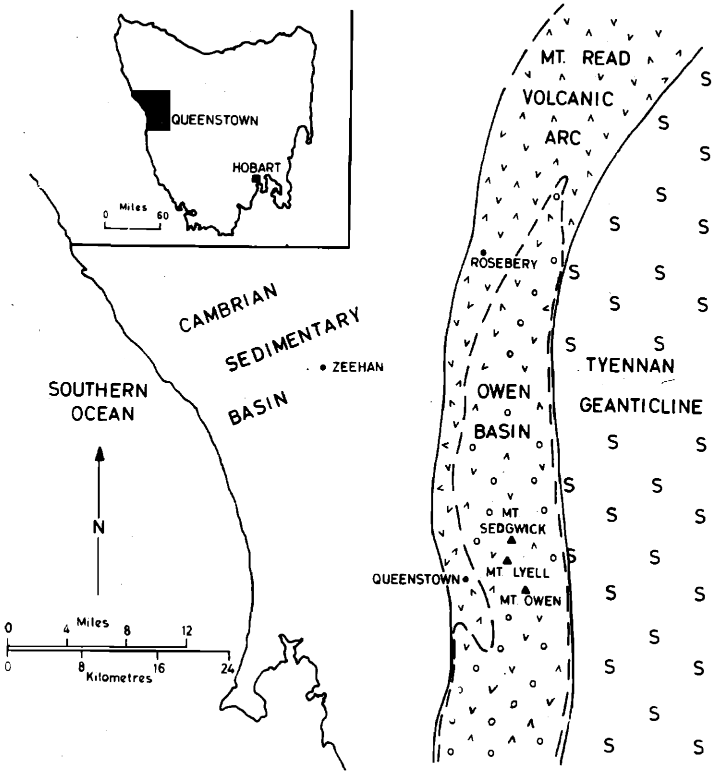

FIG. 1. Locality map showing Queenstown, the Mt. Read Volcanic Arc, and the Tyennan Geanticline.

gives the stratigraphic column for this area. The main orebodies may be classified as: massive pyrite-chalocopyrite (West Lyell); chalcopyrite-pyrite (Lyell Comstock); and bornite-chalcopyrite-pyrite (North Lyell). These ores lie in sericitized and chloritized basaltic and rhyolitic volcanic rocks (the Mt. Read Volcanics), which formed part of a narrow longitudinal strip of volcanic islands (the Mt. Read Arc) in Cambrian times (21). The Mt. Read Arc extended along the western side of the Tyennan Geanticline

TABLE 1

Stratigraphic Column for the Mt. Lyell Area

Pleistocene:	Till, sand
Tertiary:	Gossan
Jurassic:	Dolerite sill
Permian:	Tillite, sandstone
Tabberabberan Orogeny (mid-Devonian)	
Devonian-Silurian:	Sandstone, mudstone, limestone
Ordovician:	Gordon Limestone Owen Conglomerate Jukes Conglomerate
Jukesian Orogeny (late Cambrian)	
Cambrian:	Mt. Read Volcanics (keratophyre, spilite) coeval with mudstone, conglomerate, greywacke, serpentinite Success Creek Phase: sandstone, dolomite
Penguin Orogeny	
Younger Precambrian:	Quartzite, shale
Frenchman Orogeny	
Older Precambrian:	Quartz-mica-schist, garnet schist, quartzite, amphibolite

(Figs. 1, 2), which occupied the center of Tasmania and formed the eastern flank of the Cambrian sedimentary basin (the Dundas Trough). This geanticline consisted of quartzites, quartz schists, etc., of Older Precambrian age (Table 1) but was of such low relief that it supplied little or no sediment to the Dundas Trough.

In late Cambrian or early Ordovician time the movements of the Jukesian Orogeny reactivated old faults flanking the Tyennan Geanticline and produced a shallow basin or rift valley (the Owen Basin) within the Mt. Read Arc (Figs. 1, 2). The sediments deposited in the basin were initially scree-like gravels (Jukes Conglomerate) derived from the Mt. Read Volcanics, and

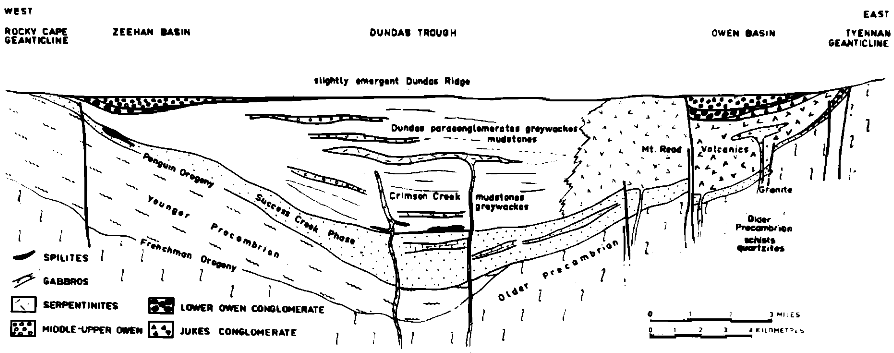

FIG. 2. Schematic cross-section of the Cambrian sedimentary basin and the Owen Basin, at the close of Owen deposition.

then siliceous gravels and sands (the Owen Conglomerate) derived from the Precambrian rocks of the Tyennan Geanticline (Fig. 3). Although there has been some controversy over the depositional environment of the Owen Conglomerate (2) it seems likely that the lower part is terrestrial (perhaps as fanglomerates) and the upper part marine (4, 20). The transition is marked by a gradual change from boulder conglomerates to mudstones, and the latter are overlain by marine shales and limestones (the Gordon Limestone).

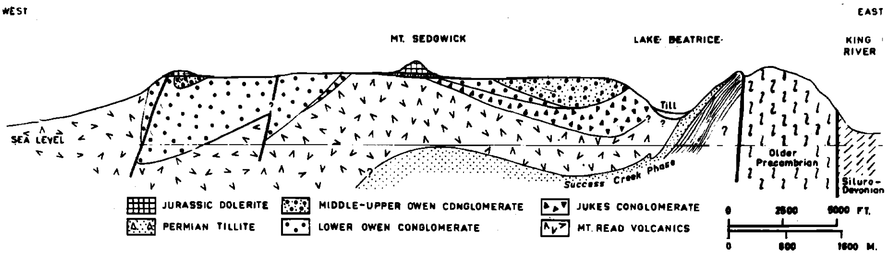

FIG. 3. Cross-section through Mt. Sedgwick, just north of Queenstown.

Details of the Owen and Jukes Formations are summarized below, the thicknesses being the maximum measured in the Mt. Lyell district.

Owen Conglomerate:

Upper Owen: 125 m: Pink and gray, coarse- and medium-grained quartz sandstones, and conglomerates with pebbles of quartz, quartzite and chert. Gray, coarse-grained, cross-bedded sandstone with chromite-rich bands. Basal, medium-pebble conglomerate, some fragments of hematite.

"Haulage" Unconformity

Purple-red, hematitic, medium-grained sandstone with characteristic vermicular bodies and two beds, up to 1 m thick, of oolitic hematitic sandstone.

Middle Owen: 366 m: Hematitic Conglomerate: coarse-pebble to boulder conglomerate, with chert and hematite pebbles. Pink or red, slightly hematitic sandstone.

Lower Owen: 244 m: Mainly yellowish-gray, pebble-to-boulder-conglomerate with minor sandstones; pebbles largely quartzite and quartz schist.

Jukes Conglomerate: 61 m: Paraconglomerates with pebbles, boulders and cobbles of Mt. Read Volcanics; some lenses of sandstone.

The Owen Conglomerate is sharply upturned along the western edge of the Owen Basin and is locally overlain by altered Mt. Read Volcanics (Fig. 3). This upturned zone is cut by Devonian WNW thrusts and transcurrent faults and locally its configuration is complex (Fig. 4). In this zone, which coincides with the western edge of the Owen Basin, the Jukes and Owen formations thin rapidly so that 2 km to the west, at Queenstown, the Jukes Conglomerate is absent and the Owen Conglomerate only 6–7 m thick.

During deposition of the upper Middle Owen sediments, poorly sorted

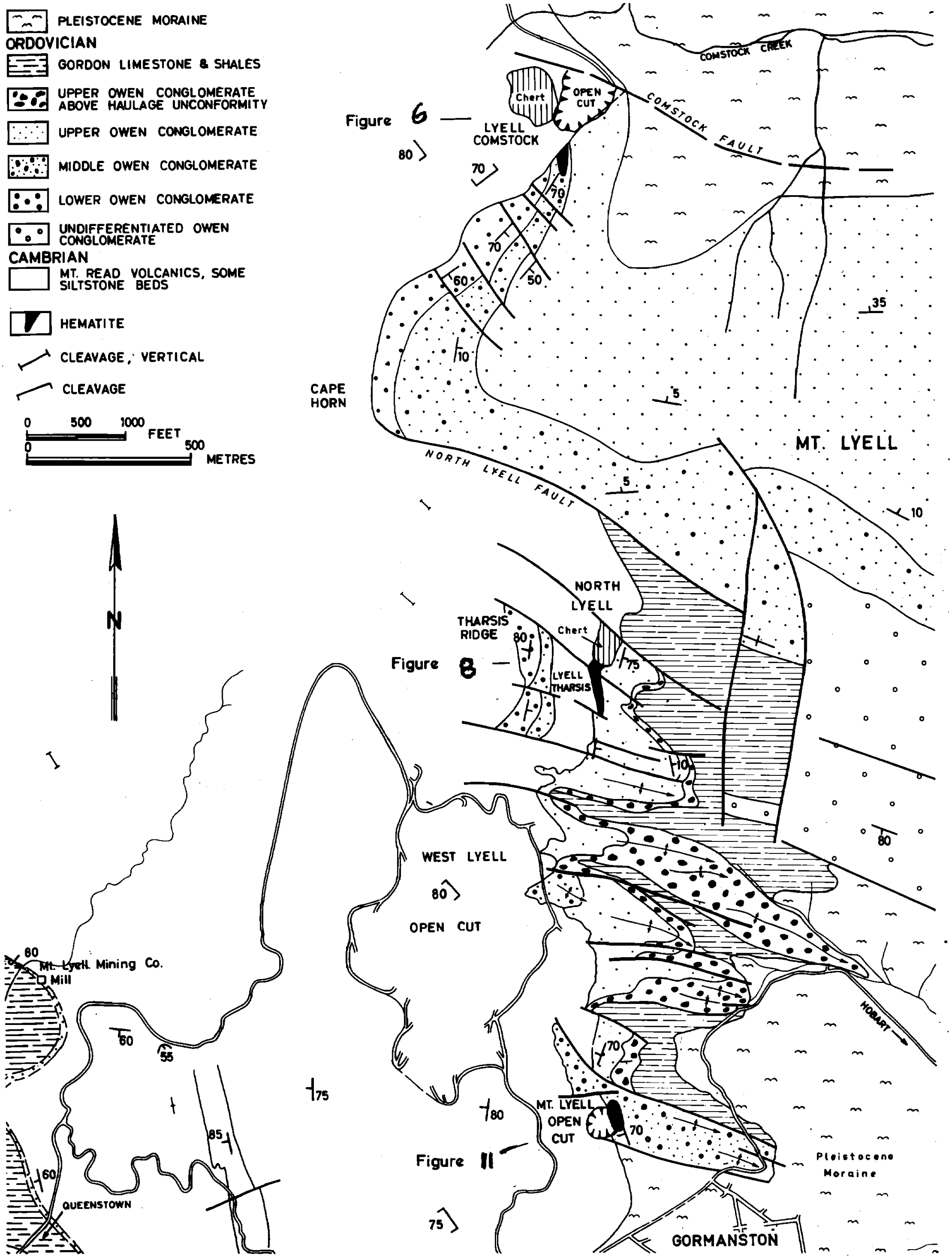

FIG. 4. Geological map of the Lyell mining area.

conglomerates were deposited in the mine area. These conglomerates consist of a hematite-quartz matrix containing pebbles and boulders up to 30 cm diameter, of hematite, chert and quartz. The conglomerates are most ferruginous and thickest near the Mt. Lyell, North Lyell and Lyell Comstock mines (Fig. 4).

THE HEMATITIC CONGLOMERATES AND THE HEMATITE BODIES

Lyell Comstock.—At Comstock the hematitic conglomerate reaches a maximum thickness of about 10 m near the sulfide ore and almost disappears about 500 m from the ore. The conglomerate consists of chert pebbles up to about 20 cm across and a few smaller hematite pebbles in a dark quartz-hematite

FIG. 5. Hematitic chert conglomerate, Middle Owen Conglomerate, Comstock.

matrix (Fig. 5). The chert is obviously derived from a steeply dipping, massive pipe of identical material overlying the lenses of chalcopyrite-pyrite ore (Figs. 4, 6). The chert body is white or pinkish and consists of a very fine-grained, interlocking quartz aggregate (31094, 32941).[1] In places the chert is brecciated and laced by crumpled and sheared iron oxide veins (Fig. 7) that consist of well-crystallized hematite with lenses of chert and quartz, and a little barite (31088–31093). X-ray lines for magnetite and the low content of FeO (Table 2) indicate the presence of maghemite.

[1] The numbers refer to specimens in the Geology Department, University of Tasmania.

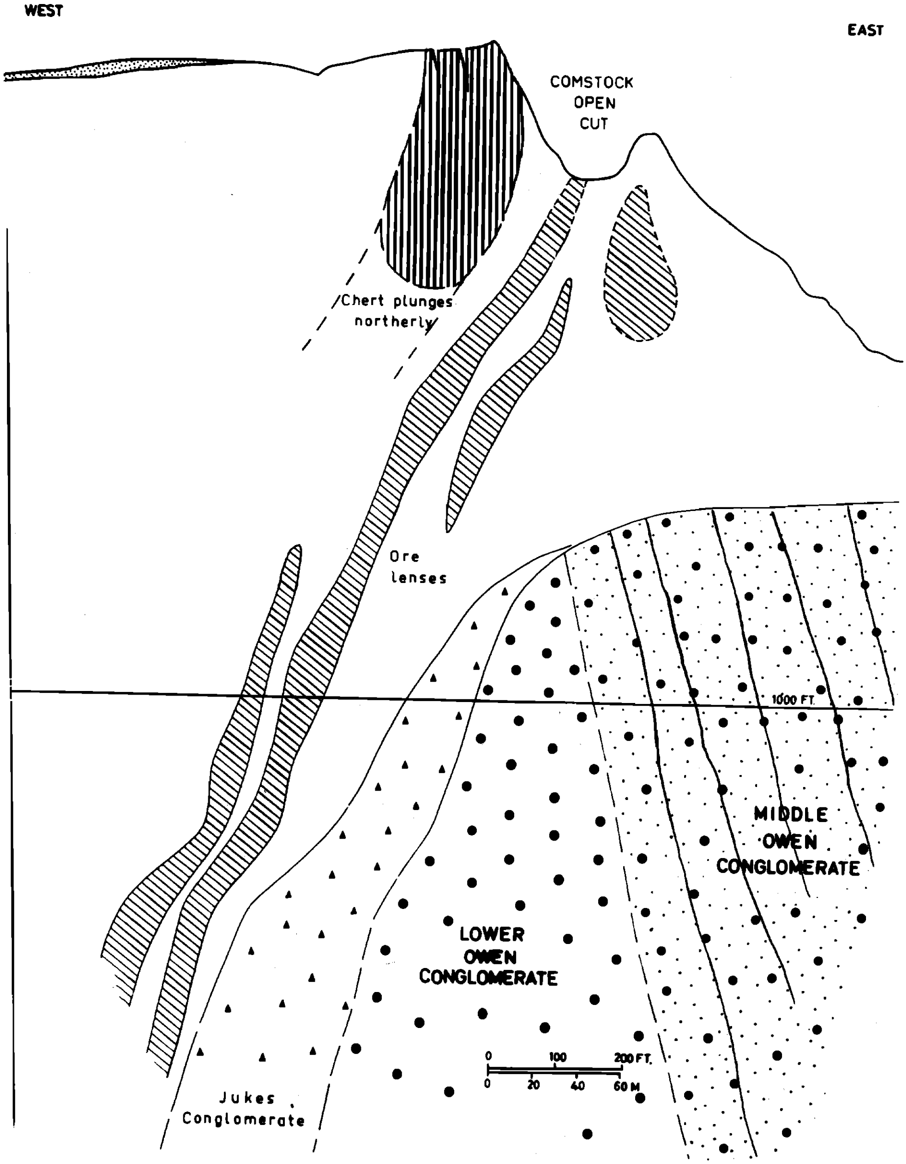

FIG. 6. Cross-section through the Comstock Mine, looking north.

Pebbles of fractured and hematite-veined chert in the hematitic conglomerate prove that both chert and hematite are pre-Upper Owen Conglomerate and it seems likely that the chert was formed during Cambrian vulcanism. Very similar goethite-veined chert overlies pyritic ore on the Cerro Colorado at Rio Tinto, Spain (*27*).

North Lyell.—Immediately east of the Lyell Tharsis–North Lyell Open Cut, Upper Owen hematitic sandstones are conformable on a layer of hematitic rock (31166–31182) which overlies mineralized and altered volcanic rocks (Fig. 4). The hematitic layer reaches a maximum thickness of about 12 m, thins both north and south, and terminates at 100 m or so from the surface (Fig. 8). The hematite body consists of rounded and angular pebbles of

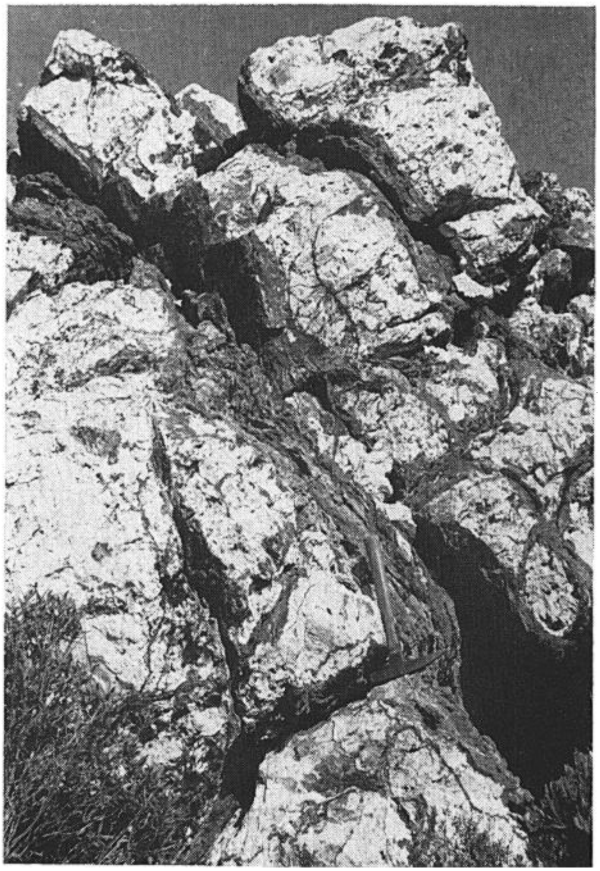

FIG. 7. Hematite veins in chert, Comstock Mine.

chert, up to 10 cm in diameter, in a hematite-rich matrix, and weathered surfaces show a layering parallel to the bedding in the overlying sandstones (Fig. 9). Parts of the hematite have a pronounced micro-botryoidal texture (Fig. 10), and interstitial areas are filled with quartz or barite. Analyses of the hematite body are given in Table 2 (numbers 2 to 6).

Edwards (5) noted that the North Lyell hematite is magnetic and polarized. It contains up to 2.7% FeO (Table 2) and X-ray studies indicate that some magnetite might be present. Dr. R. Green (University of New England) kindly determined the direction of polarity in six North Lyell hematite specimens and proved that it corresponded to a Tertiary pole position. This is probably a near-surface effect produced by chemical changes brought about by prolonged weathering and could have been developed during the Tertiary Period, when large areas of the pre-Permian surface were undergoing erosion. Samples were also taken from underground workings but

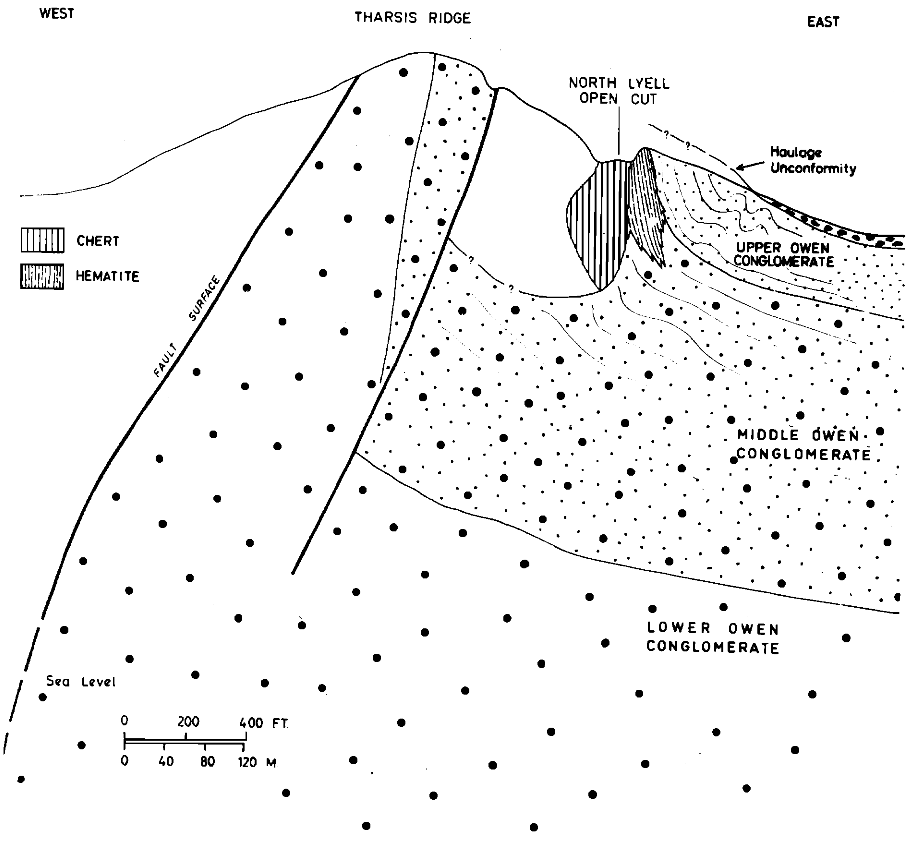

FIG. 8. Cross-section through the North Lyell Mine, looking north.

the only accessible points were to the north of the main hematite body, within the North Lyell fault zone. This zone was one of complex movement during the Devonian and this may account for the random scattering of the five determinations made. None of the readings corresponded to a Tertiary pole position.

North of the hematite, Upper Owen sandstones rest directly on a large mass of chert which lies adjacent to bornite-chalcopyrite ore. The chert is similar to the Comstock chert except that it is more brecciated and fractured, and many of the fractures contain hematite. Barite occurs sporadically and there is also a little chlorite. The chert also contains a few iron oxide veins, up to 10 cm wide (31195–97, 31095) which appear from microscope, X-ray, and analytical data (Table 2, number 7) to be almost entirely hematite. Several of them show small-scale (<1 cm diameter) botryoidal

FIG. 9. Sedimentary layering in North Lyell hematite-breccia, overturned, looking north. Pencil 10 cm long.

textures and in many cases the botryoidal bodies are elongated in the Devonian cleavage, indicating the texture is pre-Devonian.

The Iron Blow (at the Mt. Lyell Mine).—This mass was removed during open-cut mining of the adjacent pyrite (Fig. 11) and specimens are available only from dumps. From old reports (e.g., 1, 13) it appears that the hematite body was 100 m in strike length, 3–15 m wide, and extended about 60 m below the surface. Its precise stratigraphical position is uncertain because of faulting between conglomerate and altered volcanics but a reasonable reconstruction is given in Figure (7). The dump specimens (30997, 31043, 31044) consist almost entirely of hematite and barite with little or no quartz, and thus differ markedly from the North Lyell body. The lack of quartz is doubtless due to the lack of a chert mass associated with the Mt. Lyell orebody. There is practically no FeO (Table 2, number 8) and X-ray data reveal no evidence of magnetite. Peters (13, 14), Johnston (10), Thureau (23) and Ward (26) referred to gold in the hematite, and Allan (1) recorded 16 dwt. Au and 1 oz. 14 dwt. Ag per ton of hematite over a width of 6 m at the surface. A specimen from No. 2 level (32696, collected in 1910) gave relatively high values for copper, silver, and gold (Table 2, number 9).

FIG. 10. Microbotryoidal hematite with quartz, North Lyell hematite (31174).

The Mt. Lyell orebody consisted mainly of pyrite with some chalcopyrite, together with quartz and barite. Peters (14) described a bonanza of "chalcopyrite and copper-silver glance" immediately adjacent to the hematite in the sulfide ores and suggested it had developed by secondary enrichment during oxidation of the pyrite to hematite.

During the Tertiary Period a gossan developed over the pyrite orebody (1, 12, 13). The gossan varied in thickness from almost zero to 10 m and consisted of goethite and barite with a little quartz, together with gold (0.5 to 5 oz. per ton) and silver (10 to 30 oz. per ton). These values represent a considerable enrichment from the sulfide ore which now averages 0.04 oz. Au per ton and 1.5 oz. Ag per ton, though the top part of the

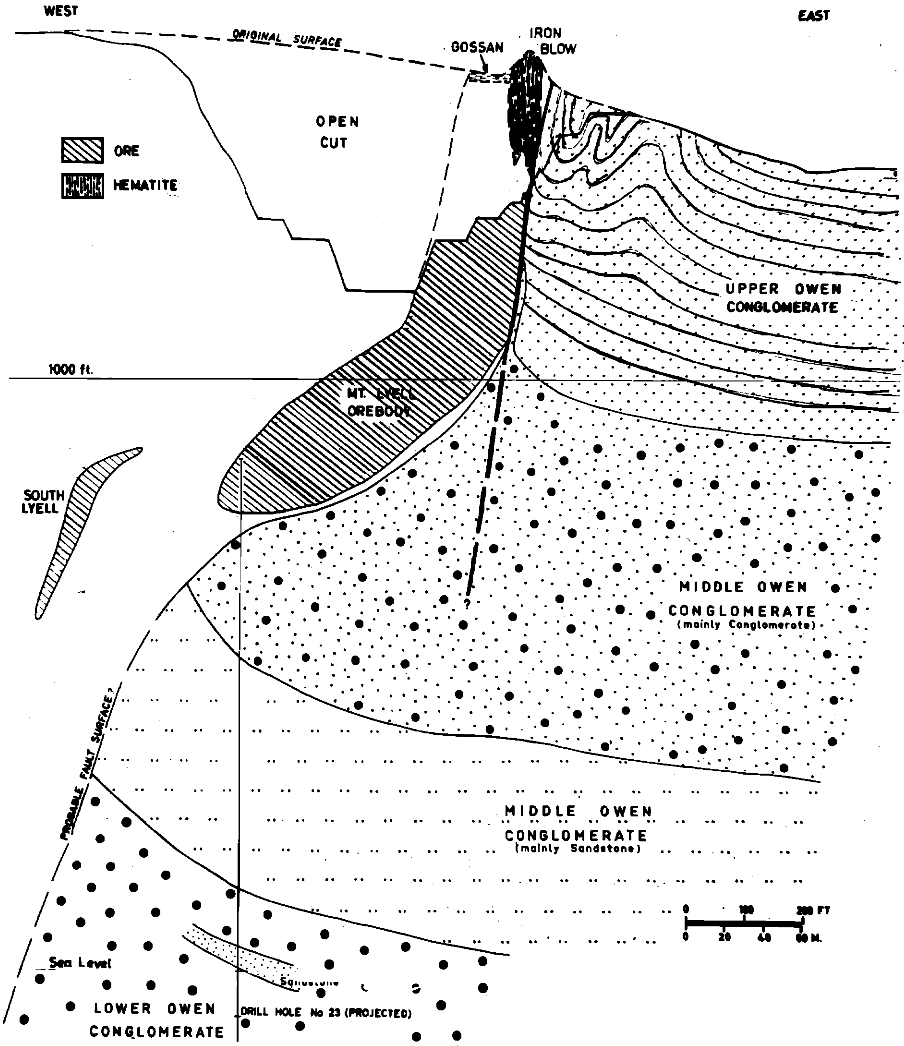

FIG. 11. Cross-section through the Mt. Lyell orebody, looking north.

orebody, which may have included some secondary material, averaged 0.095 oz. Au per ton and 2.67 oz. Ag per ton (25). Apart from the gold and silver contents, the composition of the Tertiary gossan is similar to that of the Iron Blow.

SOURCE OF THE HEMATITE

Diverse theories have been proposed for the origin of the hematite deposits, e.g.,

(a) oxidation of pyrite via limonite, or oxidation directly to hematite (1, 10, 12, 13, 23, 26);
(b) deposition from ascending solutions carrying $FeSO_4$ leached from pyrite on meeting descending meteoric(?) waters (7);
(c) leaching of hematite from the adjacent Owen Conglomerate by vadose waters (9);
(d) deposition from hydrothermal ore solutions, the iron being primary magmatic or leached from the volcanic rocks (5);
(e) development of a "basic" ferruginous front during sulfide mineralization and silicate metasomatism (3);
(f) transfer of iron from adjacent volcanic and sedimentary rocks during sulfide mineralization (25).

The field evidence shows that the chert masses of North Lyell and Comstock were exposed to erosion during deposition of the Middle Owen sediments, and the presence of detrital chert throughout the Upper Owen suc-

TABLE 2 - COMPOSITION OF THE HEMATITES AT MT. LYELL

	1	2	3	4	5	6	7	8	9
SiO_2	27.88	1.64	19.56				1.20	0.50	
TiO_2	nil	0.08	0.32				nil	nil	
Al_2O_3	0.81	1.65	1.80				1.34	1.08	
Fe_2O_3	64.60	88.60	72.60				95.90	42.13	
FeO	1.22	1.72	2.56				0.81	0.16	
MgO	nil	0.12	0.08				0.06	0.07	
CaO	0.36	0.63	0.06				0.08	0.16	
Na_2O	Tr.	0.19	0.25				0.02	0.11	
K_2O	0.06	0.06	0.03				0.19	nil	
H_2O+	0.49	0.66	1.15				0.51	0.32	
H_2O-	nil	0.10	0.06				0.16	0.05	
MnO	0.02	0.04	0.04				Tr.	Tr.	
P_2O_5	0.09	0.88	0.75				0.02	0.01	
$BaSO_4$	4.54	4.01	1.15					56.00	
Total	100.07	100.38	100.41				100.29	100.59	
Cu	600	Tr.	Tr.	300	10,000	200	700	200	800
Au	<3	Nil	Nil	<3	<3	<5	<3	<3	<5
Ag	0.1	Nil	Tr.	0.1	1	3	1	3	100
Mn	300	400 (310)	400 (310)	600	6,000	2,000	200	150	1,400
Ti	100	800 (500)	3,200 (2,000)	2,000	1,500	2,000	100	50	250
P	(200)	(1,900)	(1,650)	10,000	4,100	3,700	110 (40)	A: 140 (20) B: 150 C: 410	

1. Hematite vein (31199) in Comstock chert. 2. North Lyell hematite (31182). 3. North Lyell hematite (32940). 4. North Lyell hematite (31175). 5. North Lyell hematite at base (31167). 6. North Lyell hematite at base (31734). 7. Hematite vein in North Lyell chert, north end of Tharsis Ridge (31196). 8. Iron Blow hematite-barite (31045). 9. Iron Blow hematite-barite No. 2 level (32696). Oxide analyses by Department of Mines Tasmania. Trace analyses by spectrophotometer and optical spectrograph, Australian Mineral Development Laboratories. Bracketed numbers derived from oxide analyses.

cession in the mine area indicates that the masses remained exposed until finally covered by the overlying Gordon Limestone. It is also clear that a source of iron oxide was exposed during Middle Owen deposition near Comstock, North Lyell and the Iron Blow. The coarse-grained, poorly sorted structure of the North Lyell body and the Comstock conglomerate suggests local derivation. The source of the chert is known but the source of the hematite is not immediately obvious. Weathering of hematite-magnetite veins, such as are found elsewhere in potassic rhyolites in the Mt. Read Volcanics, could form limonitic screes under subtropical conditions of high humidity (18) but there are no such veins in the Mt. Lyell area. The small size of the veins in the chert masses makes them unlikely sources and at the Iron Blow it would be necessary to imagine veins that have since been completely removed by erosion. Probably the most significant fact is the coincidence of the three hematite concentrations with the three principal sulfide concentrations of the Lyell orefield: the pyrite ore of the Mt. Lyell mine, the bornite-chalcopyrite-pyrite ore at North Lyell, and the pyrite-chalcopyrite ore at Comstock. These considerations indicate that the hematites may be dehydrated goethite masses derived in part from oxidation of outcropping sulfide ores.

DISCUSSION

The North Lyell and Comstock bodies may have been ferruginous screes but the purity of the Iron Blow and its proximity to enriched zones in the contigouous pyritic orebody indicate little or no transport and mixing with country rock.

The barite of the Iron Blow may be largely residual from the sulfide ore, as in the Tertiary gossan, and no transport mechanism is required. However, this can hardly be true for the interstitial barite in the North Lyell hematite though it is difficult to see how barium sulfate could be transported in the sulfate-rich waters prevailing during sulfide oxidation.

The botryoidal textures suggest that the hematite (or its predecessor) was at least partly precipitated from solution, and the spheroidal surfaces, and radial and concentric cracks (Fig. 10), indicate precipitation from colloidal solutions. Iron oxides commonly precipitate as gels to form amorphous limonitic material, or crystallize to goethite, hematite (6, 11) or even magnetite (22) but colloform hematite is rare (6). However, such hematite could develop by dehydration of colloform iron hydroxides during later metamorphism. Posnjak and Merwin (15) were able to dehydrate solid goethite at temperatures above 145° C at low pressures within a few weeks, and Tunnel and Posnjak (24) found that in the presence of 0.1 M HCl solution the transition temperature dropped to about 100° C. Smith and Kidd (19) found that in alkaline conditions (0.1 M NaOH) the phase change took place at about 165° C at low pressure, the temperature increasing slightly with increasing pressure (5° C/1,000 atmospheres). Schmalz (18) found a more marked increase with pressure in more or less pure water, and at 800 atmospheres goethite was stable up to about 165° C.

Hematite is rare in gossans so that if the Lyell hematites are correctly interpreted as gossans, they are likely to be derived from goethite. A reasonable estimate of the overburden deposited between the early Ordovician and Devonian orogenies is about 3,000 m (21), sufficient to raise the temperature at the bottom of this column to at least 100° C, and possibly considerably higher, during the Devonian orogeny. This temperature is probably adequate to bring about dehydration of the goethite.

In order to examine further the suggestion that these hematite bodies are gossans, a reconnaissance study of their trace elements was made, with results as follows:

Phosphorus tends to be enriched in gossans compared to the source material (8, 27). For the North Lyell area, it can be seen from Tables 2 and 3 that phosphorus is considerably higher in the hematite than the adjacent ore. However, the Blow hematite does not show a similar trend (even allowing for the presence of barite), a feature that might possibly be related to the limited transport relative to the North Lyell material.

Titanium and manganese are likely to show enrichment during the weathering cycle (17) and a similar relationship to that shown by phosphorus is

TABLE 3

	Mt. Lyell or Blow Mine	North Lyell Mine area
	(31191)	(31805, 10719, 33981)
Mn	300	10; 100
Ti	500; 200 (± 50)	800; 100; 2,800 (± 50)
P	710; 450 (± 20)	170; 160; 410 (± 20)

Analyses for Ti and P by spectrophotometric methods, and for Mn by optical spectrography Australian Mineral Development Laboratories.

evident between the different hematite occurrences and the sulfide ores (Tables 2, 3). These results, though not providing proof, are compatible with a secondary origin for the hematites.

Though existing knowledge of the Owen Conglomerate is limited, it is likely that the Lyell mine area formed a topographic high on the western edge of the Owen Basin and that the Lower and Middle Owen sediments were deposited under terrestrial (2) and possibly arid (4) conditions. Hence climatic and topographic conditions could have been favourable for gossan formation.

In conclusion, there seems to be good grounds for believing the intuitive suggestion made by earlier workers (e.g., 1, 10, 26), that the hematites are dehydrated gossans.

ACKNOWLEDGMENTS

Grateful acknowledgment is made of the co-operation received from the Mt. Lyell Mining and Railway Co. during this study and of discussions with Mr. G. Hudspeth, General Manager, and Mr. R. G. Elms, Chief Geologist. Dr. R. Green of the University of New England kindly determined the polarity of the hematites.

This study formed part of a project financed by the University of Tasmania and the Australian Universities Research Grants Committee.

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Submitted April 10, 1967
Resubmitted June 18, 1967

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