The Geology of the Laxey Lode, Isle of Man

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Abstract: An analysis of the geological relationships of the Laxey zinc-lead ore deposit derived from the literature and from unpublished reports is presented. The deposit is a single lode 2km long and up to 8m wide with a north-south trend and an easterly dip of about 10° from the vertical. It is emplaced within the Lonan Flags (Manx Group, Lower Ordovician) and is crossed by several "slide" faults, some offsetting the lode. The lode post-dates the folding and metamorphism of the Manx Group and emplacement of microgranite dykes, probably in Carboniferous times. It is suggested that Carboniferous mudrocks were the source of the metal ions. The ore was mainly sphalerite with less abundant galena and some chalcopyrite. Some of the galena was argentiferous. It is estimated that over 1 million tons of ore containing 3-8% Pb, 5-15% Zn and 2.5% Cu were extracted.

Introduction

Lying in the Irish Sea midway between England and Ireland, the Isle of Man was noted in the 19th century for its rich lead-zinc-copper mines. Of these the Great Laxey Mine was reputed to be one of the richest zinc-lead mines in Europe with over one million tons of ore extracted before mining ceased in 1919. Descriptions of the associated relics of surface installations, particularly the giant Lady Isabella water-wheel, are available (Jespersen, 1970; Cowin, 1973; Kniveton *et al.* c.1993). Jespersen discussed the mechanics of pumping in detail and included reminiscences from former miners of some of the more recent events in the mine's history. There are also several general accounts of the history of mining (Lamplugh, 1903; Skelton, 1956; Mackay and Schnellmann, 1963; Garrad *et al.* 1972; Robinson and McCarroll, 1990) but records of the geology of this important lode are minimal and misleading.

Laxey town lies at about 80m above sea level near the east coast of the Isle of Man and the mine was a few hundred metres farther inland (Fig. 1). No detailed study of the Laxey ore deposit using modern geological methods is possible at present as the mining effectively ceased with a strike in 1919 and the mine was officially closed in 1929. Most of the workings are no longer accessible owing to flooding, collapse or infilling. The few available descriptions of the geology are either incomplete or difficult to interpret. However, some idea of the lode's relationships can be gained from the old accounts and the results are presented here. They provide an illustration of the difficulties of using old records to judge whether an ore-body really has been exhausted. Little has been said on the genesis of the lode in previous literature and an attempt is made herein to rectify this omission.

Data have been assembled from mine plans coupled with observations made at the surface and in the few accessible adits. More could be learnt by a thorough study of the nature and disposition of the host rocks in the accessible shafts and adits by anyone prepared to take the risk of underground exploration of long-disused workings. Further data could also be derived from waste material in the river and from cobbles on the beach, though most of the waste heaps have been removed or are built over. Some mineralogical data could doubtless be obtained from specimens in the Manx Museum.

Previous Research. There are few geological accounts of the mineral lode. In preparing the Geological Survey Memoir, Lamplugh (1903) had the advantage of being able to see the mine whilst it was still working and the following text draws from his work. Lamplugh and Dewey's report (1925) on copper ores largely repeated the Memoir while Carruthers and Strahan (1923) and Skelton (1956) added a few details concerning the mining history. These accounts were all summarized in an unpublished report by Mackay and Schnellman (1963 — copy in the Manx Museum library) which also provided information culled from other mining archives in the Manx Museum. As most of the mine is below sea level it has been flooded since working stopped in 1919 but a main adit driven northwards is still above water level. The northern section of this was reached by expert mine explorers in 1971, 1974 and 1982. Unfortunately the explorations described by Richards and Atherton (1971) and by Warriner and Gillings (1983) were undertaken without a geologist present and added little to geological knowledge. A general geological account of the Isle of Man with an outline of the Laxey area was given by Ford (1993).

Stratigraphic and Structural Overview. According to Simpson's (1963) geological map of the subdivisions of the Manx (Slate) Group, the Laxey Lode is emplaced within the Lonan Flags (Lonan Formation of Ford's revised nomenclature, 1993) (Fig. 2). The Lonan Formation, in common with most of the Manx Group, is now known to be of Early Ordovician (Arenig) age.

The accessible levels of the mine and the few surface exposures reveal an alternation of cleaved siltstones and argillaceous host rocks which are more like Simpson's (1963) Maughold Banded Formation than the Lonan Flags. The latter vary from massive sandstones (Agneash Grits in some accounts) to pelites along the east coast of the Isle of Man and, without detailed re-mapping, Simpson's assignment of the beds around the Laxey Lode to the Lonan Flags must remain uncertain. Furthermore,

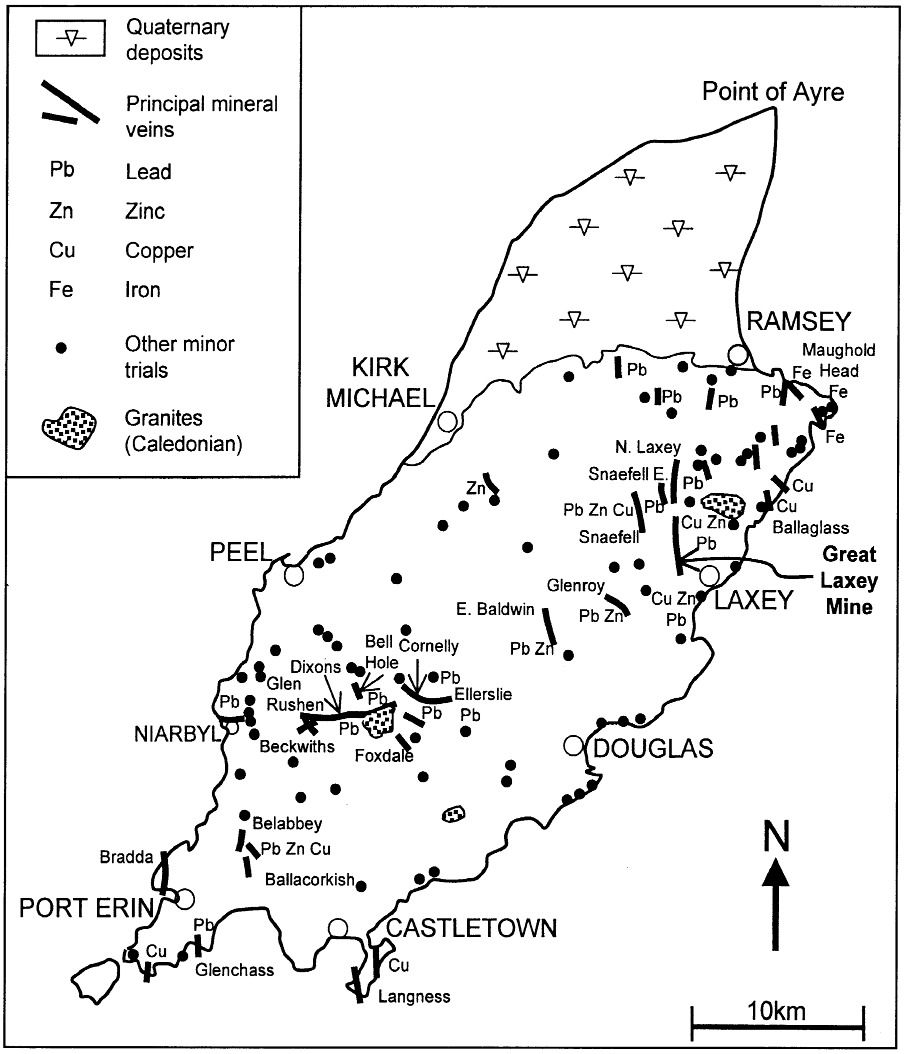

Fig. 1. Sketch map of the Isle of Man showing the location of the Laxey Lode in relation to other mineral veins, mines and trials.

Lamplugh (1903) noted argillaceous strata in the deeper parts of the mine near Dumbell's Shaft, and "hard grits" to the north; neither was thought to have been as receptive to mineralization as the thinner flaggy beds in the main part of the mine.

The Laxey Lode trends approximately north-south at an oblique angle to the strike of the "slates" (Figs. 2 and 3). Indeed, Simpson's (1963) map indicates that the strike of the host rocks is roughly WSW-ENE, i.e. at about 60-70° to the strike of the Lode. This agrees with Lamplugh's (1903) observations and with the sections of slate visible along both the Mooar Water stream banks and in the accessible adits. The Mooar Water was diverted through a tunnel to allow space for mine installations between the Engine and Welsh Shafts (variably spelled Welsh or Welch on old plans). According to Simpson's structural analysis, the Lode crosses the Dhoon anticline but it has not been possible to define the axis in the accessible adit. Lamplugh (1903) noted that the average direction of dip of the beds in the southern section of the mine was 160° whereas in the north the dip direction had changed to 340°, supporting the concept of the Lode crossing an anticline. Later, Lamplugh and Dewey (1925) made the apparently inaccurate comment that the strike of the highly folded "slates" was at right angles to the lode, though the comment might be taken to hint that subsidiary folds have been superimposed on the Dhoon anticline.

The Laxey Lode and Mine

The Laxey Lode has generally been reported as a single vein or fracture-fill about 2 kilometres long (Mackay and Schnellmann, 1963). It lies almost beneath the Mooar Water stream, close to the village of Agneash (Fig. 3). It was eventually worked to a depth of about 500m below sea level. The Lode trends almost due north in its southern section swinging to nearer 350° near Dumbell's Shaft. It is steeply inclined to the east at an angle slightly greater than 10° from the vertical (Lamplugh, 1903; Garrad *et al.*, 1972). Lamplugh noted that the Lode filling was lenticular from a few centimetres to about 8 metres wide. No record has been found concerning slickensides on the vein walls or of the direction of movement — was it a normal fault or a wrench fault? Mackay and Schnellmann's Figure 10 (amended and redrawn here as Fig. 4) is a profile along the Lode based on the mining company's section dated 1887, housed in the Manx Museum's archives. The profile contains several inaccuracies though it is not clear to what extent these reflect mistakes in the mining company's plans or in Mackay and Schnellman's interpretation of them. Firstly, sea level is shown much lower than it really is (Fig. 4 has been revised to give a correct position). Secondly, it shows Dumbell's Shaft as having been sunk from adit level only, though it had been raised to the surface by 1877, at least 10 years earlier than the date of the plan. Finally, there are large blank areas between those shaded as having been stoped out — whether these represent barren or unworkable parts of the Lode or whether there were earlier unrecorded workings is unknown. Although levels in the deeper parts of the mine (driven up to 1919) have been added to the plan, no stoped areas are shown though surely some were worked. However, the profile does suggest that the mine was richest in ore adjacent to a series of slide faults (see below).

The mine plan used by Jesperson (1970) is that preserved in the Manx Museum. He found that it did not fit the surface features accurately and deduced that the mine surveyors had failed to make adequate allowances for changes in magnetic declination from 1858 until the mine closed in 1919. Accordingly, Jespersen "rewarped" the plan to allow for these changes. However, he only corrected that part of the plan extending a little to the north of Agneash where the 1:2500 Ordnance Survey map ended. A reduced version of Jespersen's plan is given in Fig. 5. Furthermore, Warriner and Gillings (1983) also found that Jespersen had made an incorrect assumption about the gradient of the adit, which in turn had an effect on the assumed depths and inclinations of the shafts. In spite of a recommendation by Warriner and Gillings (1983) that the Agneash Shaft should be surveyed in detail down to the adit, it was not practicable to do so at the time and the shaft has now been filled and capped, precluding any future survey. Jespersen's plan suggested that Agneash Shaft had an average inclination of about 9.8° from the vertical, but Gillings (personal communication) has suggested that the inclination was nearer to 8° down as far as the adit. In contrast, Welsh Shaft appears from Jespersen's plan to have an inclination of about 15° down to the adit. These variations in inclination are less obvious in Jespersen's shaft sections (Fig. 6).

In spite of the above variations of inclination the plan indicates a general angle somewhat greater than 10° from the vertical, as the lower levels are displaced horizontally to the east by about 100

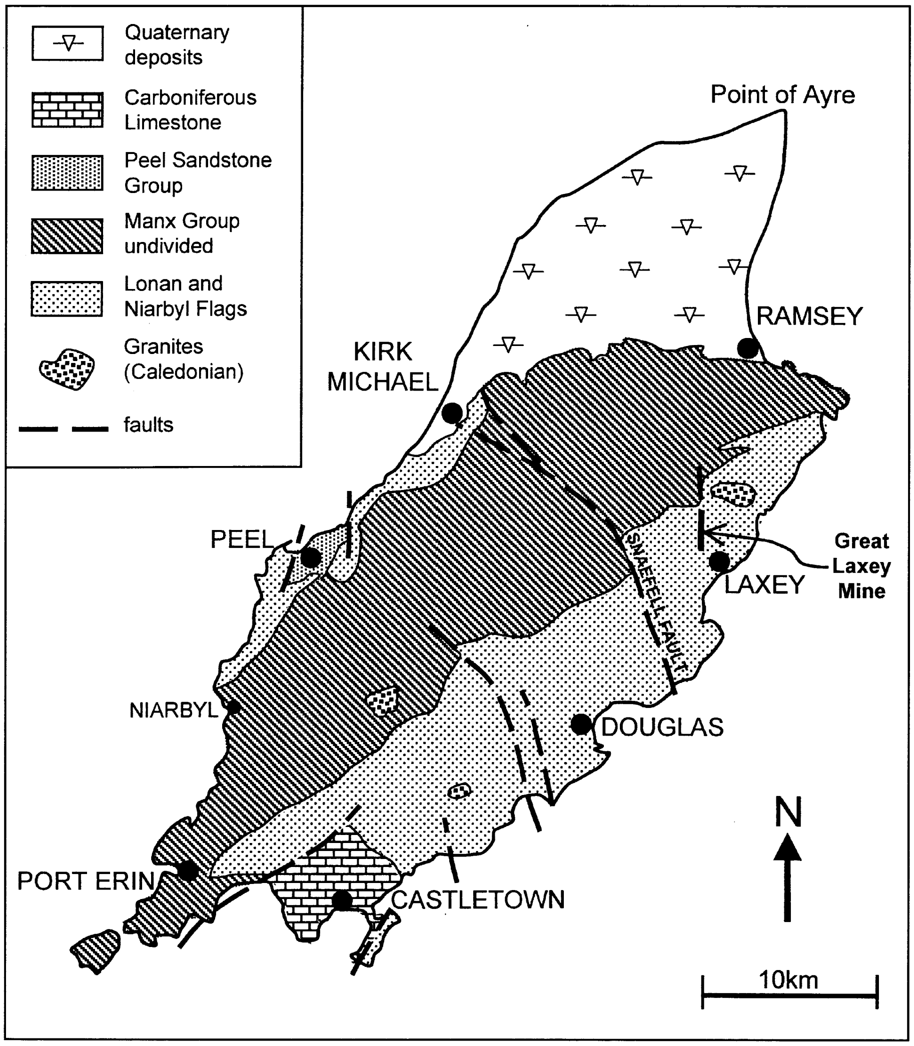

Fig. 2. Sketch geological map of the Isle of Man, based on Simpson (1963), showing the location of the Great Laxey Mine.

metres at a depth of 220 fathoms (approximately 400m) below the adit. The main shafts followed this slope and are inclined with the vein, as indicated on Fig. 6 which is adapted from Jespersen's (1970) Figure 193. The inclination of the shafts is variable as shown by the irregularities in Fig. 6. Dumbell's Shaft was said to be nearly vertical by Garrad *et al.* (1972) but in fact it has an inclination similar to the other shafts, i.e. about 10° from the vertical throughout its 660 metre depth. However, below the 230 fathom level (420m below the adit; about 500m from the surface) the working levels are almost superimposed on one another in plan view, implying that the vein, not the shaft, becomes almost vertical at this depth.

Branches splitting off the main Lode in the Laxey Mine were noted by Lamplugh (1903) and both an East Branch and an East Lode appear towards the northern end of Jespersen's (1970) plan. They were apparently found by cross-cuts driven east from the Main Lode. If these are parallel to the inclination of the Lode they may be the same vein. Some 500m of drivage suggests that some ore was found. By analogy with the Derbyshire scrins that diverge from rakes, the branch veins may represent Reidel shears, with the corollary implication that the main Laxey fracture is a wrench fault. Lamplugh commented that the branches were said to carry little ore. He also noted a few closely parallel quartz veins with little or no ore. The positions and directions of any other branch veins were not recorded.

The richness of the ore, i.e. the ratio of ore to gangue, is hard to judge though values were said to be poor in the northern extremes of the mine where the yield was "one ton lead and two tons zinc per fathom" (Carruthers and Strahan, 1923). Exactly what this means is uncertain. The metal content is likely to have been assessed from concentrates after preliminary processing; "per fathom" may have meant "per square fathom", though how this was estimated is again uncertain. It is more likely that it referred to a section of vein one fathom high and one fathom forwards, with the bargains being struck according to the width of the vein. As far as is known only the vein itself was extracted avoiding unnecessary removal of country rock. Based on the above figures, Skelton (1956) estimated that the ore carried 5.8% lead metal and 7.7% zinc metal, and he judged these figures to be barely enough to make working viable. Therefore the better parts of the vein must have had higher ore values. Mackay and Schnellmann (1963) deduced ore grades as 3-8% Pb, 5-15% Zn and 2-5% Cu, based on estimates derived from annual production figures. They estimated that 1.2 million tons of ore yielded 232,981 tons of zinc concentrates, 12,276 tons of copper concentrates and 70,138 tons of lead concentrates (elsewhere in their report Mackay and Schnellmann gave different figures — 282,891 tons Zn; 8,864 tons Cu). The lead ore was said to have yielded an average of 40 ounces of silver per ton though production figures do not confirm this. The

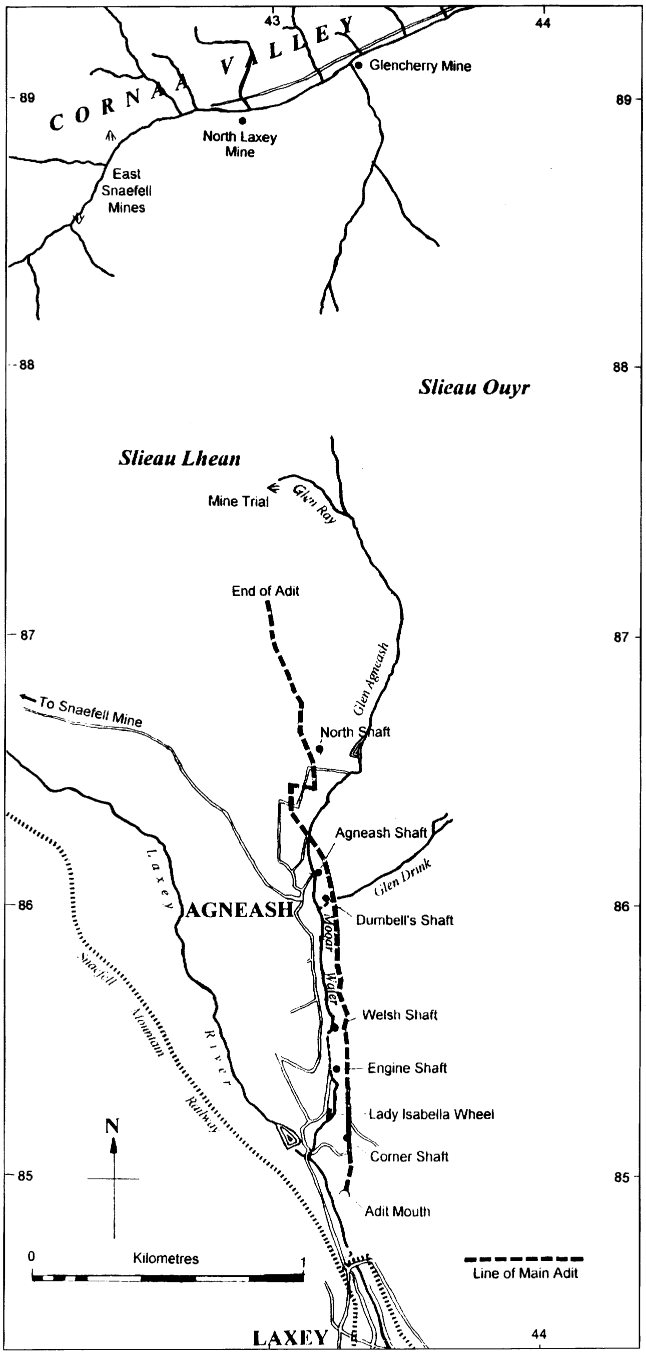

Fig. 3. Key map of Great Laxey Mine and the Cornaa Valley.

southern sections of the mine, particularly between the Big and Welsh Slides, (the nature of the slides is discussed later) apparently carried a higher proportion of copper ore, mainly chalcopyrite (Lamplugh and Dewey, 1925). If it were possible to relate annual production figures to an annual record of stoping, then an alternative method of estimating the richness of the ore in different sections of the mine might be available.

The Minerals. The ore minerals present are sphalerite, galena, pyrite and chalcopyrite whilst the gangue minerals are mainly quartz, calcite, dolomite and siderite. Minor amounts of baryte were also raised. Limited quantities of pyrite, marcasite, pyrrhotite and pyromorphite were present; oxidation

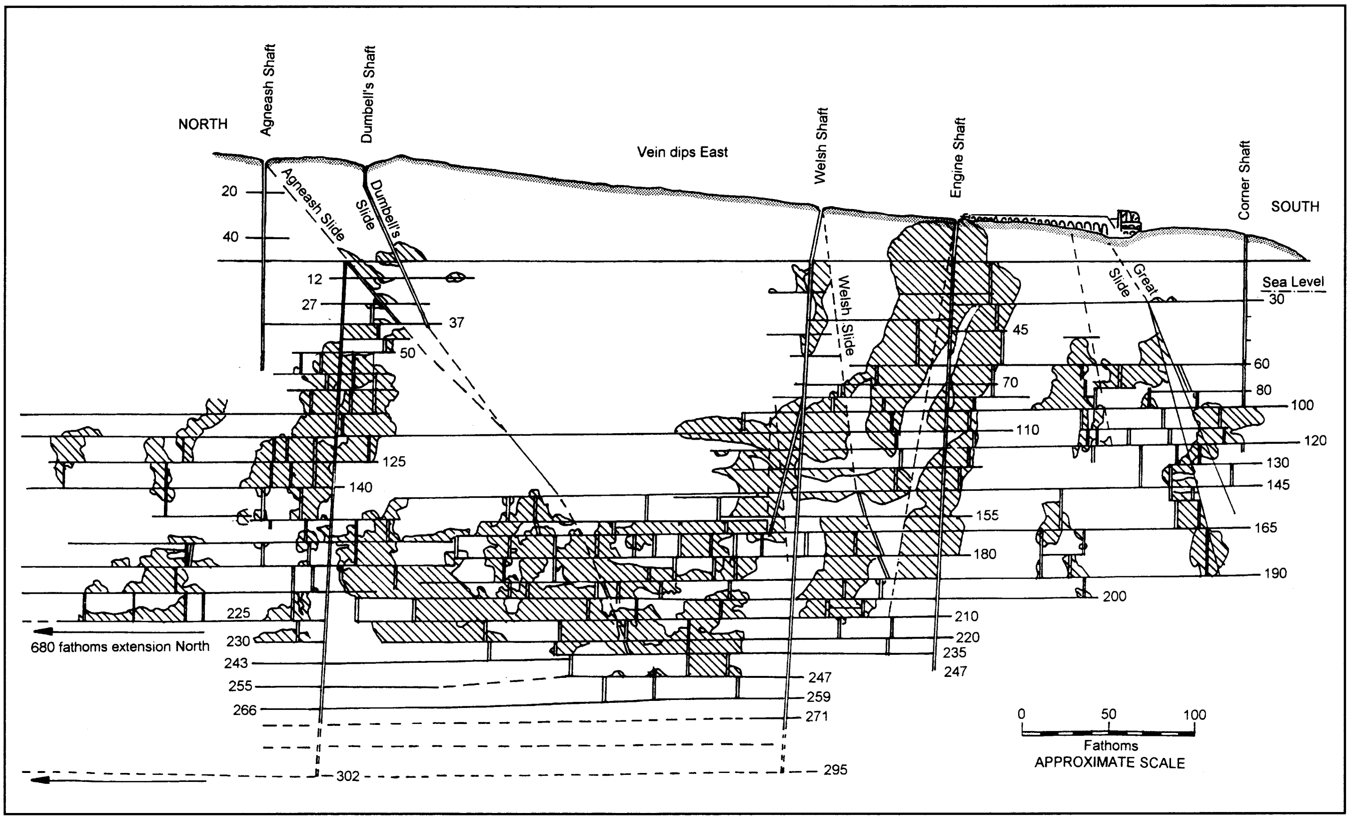

Fig. 4. Profile along the Laxey Lode showing shafts, levels and worked out stopes as they were in 1887, with broken lines showing lower levels worked up to 1919. Amended and redrawn after Mackay and Schnellmann's (1963) Fig. 10, which is based on a section in the Manx Museum. The numbered levels are only approximate depths as no allowance was made on the original for the gradient needed for drainage.

products include malachite, chalcanthite, cerussite, melaconite, melanterite, smithsonite (calamine in old literature), steatite and umber, mainly in the upper levels (Smyth, 1888, quoted in Lamplugh, 1903, pp. 572-574). Most of the galena was argentiferous but no silver minerals have been recorded. No description of the mineral textures seen across the Lode has been traced, but the sulphides were said to be in ribs apparently parallel to the walls and interlayered with the gangue minerals. Freely grown crystals of both sulphides and gangue minerals occurred in vughs, the source of specimens in the Manx Museum and other old collections. The mine was noted for its fine crystals of chalcopyrite and dolomite. The southern section of the Lode, i.e. that with copper ores, had rather more dolomite than calcite. Some records of dolomite apparently included siderite as the two minerals are not always easily distinguishable.

A thin vein of "anthracite" found on the hanging wall was subsequently identified as thucholite, a uranium-bearing hydrocarbon rather like anthracite in appearance (Davidson and Bowie, 1951, pp. 4-5). Under the microscope the thucholite was found to consist of a hydrocarbon enclosing micron-sized spherules of uraninite and pitchblende. Davidson and Bowie proposed that the uraninite and pitchblende originated from a hydrothermal mineralizing phase, that the hydrocarbon was introduced as a fluid or even gas, and that polymerization, coagulation and syneresis followed. The uraniferous hydrocarbons led Parnell (1988) to imply that mineralization took place when there was a cover of Carboniferous strata. He also found traces of other metals in the inclusions, notably Ni, Co, Bi, Sb and W.

In the early 1950s the UK Atomic Energy Authority investigated alleged uranium resources at Laxey and elsewhere on the Isle of Man and it seems that some dump material from Laxey and the Snaefell Mine was taken away for testing with negative results (Hollis, 1987).

In summary, the Lode is composed largely of a gangue of quartz with subsidiary calcite and dolomite enclosing brecciated slate clasts, with the metal sulphides tending to be concentrated near the walls but sometimes scattered through the whole vein or lining vughs.

The 'Slides'. The Lode was affected by several so-called slides, which appear to be faults offsetting the vein from its regular trend. As no geological description of any of these dislocations is available, the exact type of faulting must remain uncertain. Both Lamplugh and Dewey (1925) and Mackay and Schnellmann (1963) regarded the slides as normal faults crossing and offsetting the vein. The latters' report included a profile along the lode showing the slides, most of which are shown to come to surface close to where the shafts were sunk (Fig. 4). Lamplugh (1903) noted that the slides were not mineralised and ranged in orientation from east-west to about WSW-ENE, offsetting the vein by between 10 and 70 feet (3-20m). The Big Slide was noted to be about 160 yards (c.150m) south of Engine Shaft and "carrying the vein 10-20 feet westwards on the south side", i.e. a dextral displacement, which "dipped south at 70° from the horizontal splitting into two branches below 30 fathoms". Lamplugh's (1903) brief comments make the slide dislocations appear more complex than simple normal faults. Welsh Slide, coming to the surface near Welsh Shaft, affected the Lode in a similar manner but was a little steeper. It is interesting that neither of these slide offsets has any substantial effect on the position of the adit or levels on the mine plans (Fig. 5), as might have been expected. This suggests that they were of minor structural importance only. Dumbell's Slide dipped south and was intersected by Dumbell's Shaft at about 20m depth. Deeper still, it was joined by a steeper slide. In the northern limits of the mine, slides apparently dipped northwards and shifted the lode in the opposite direction to those noted above. The positions of other slides are not shown on the mine plan though there were known to be several south of Corner Shaft. Lamplugh (1903) thought the latter were responsible for terminating the lode to the south, as exploratory adits failed to find any continuation of the Lode to the south.

The 1982 re-survey of the northern section of the Main Adit located a dextral cross-fault about 330m north of Agneash Shaft (Figs. 2 and 5); this displaced the Lode at adit level by 59m to the east (Warriner and Gillings, 1983) but curiously the deep

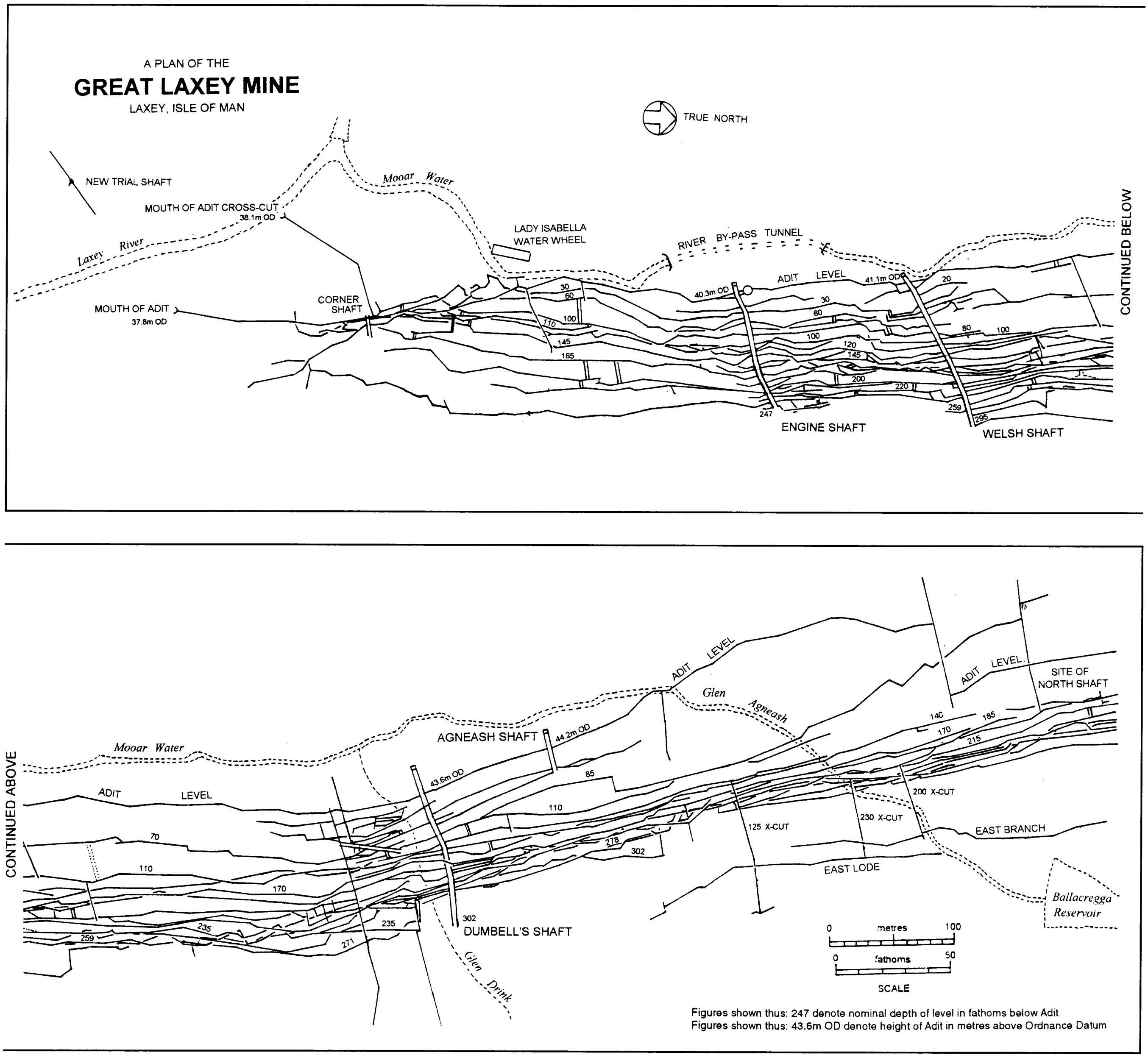

Fig. 5. Plan of levels in Great Laxey Mine, after Jespersen's "rewarped" plan of 1970 (simplified by Andy Gillings from Warriner and Gillings, 1983, Figure 3). Depth of shaft bottoms are given in fathoms (1 fathom = 1.83m). Altitudes of the Main Adit portal and of the adit at shaft intersections given in metres.

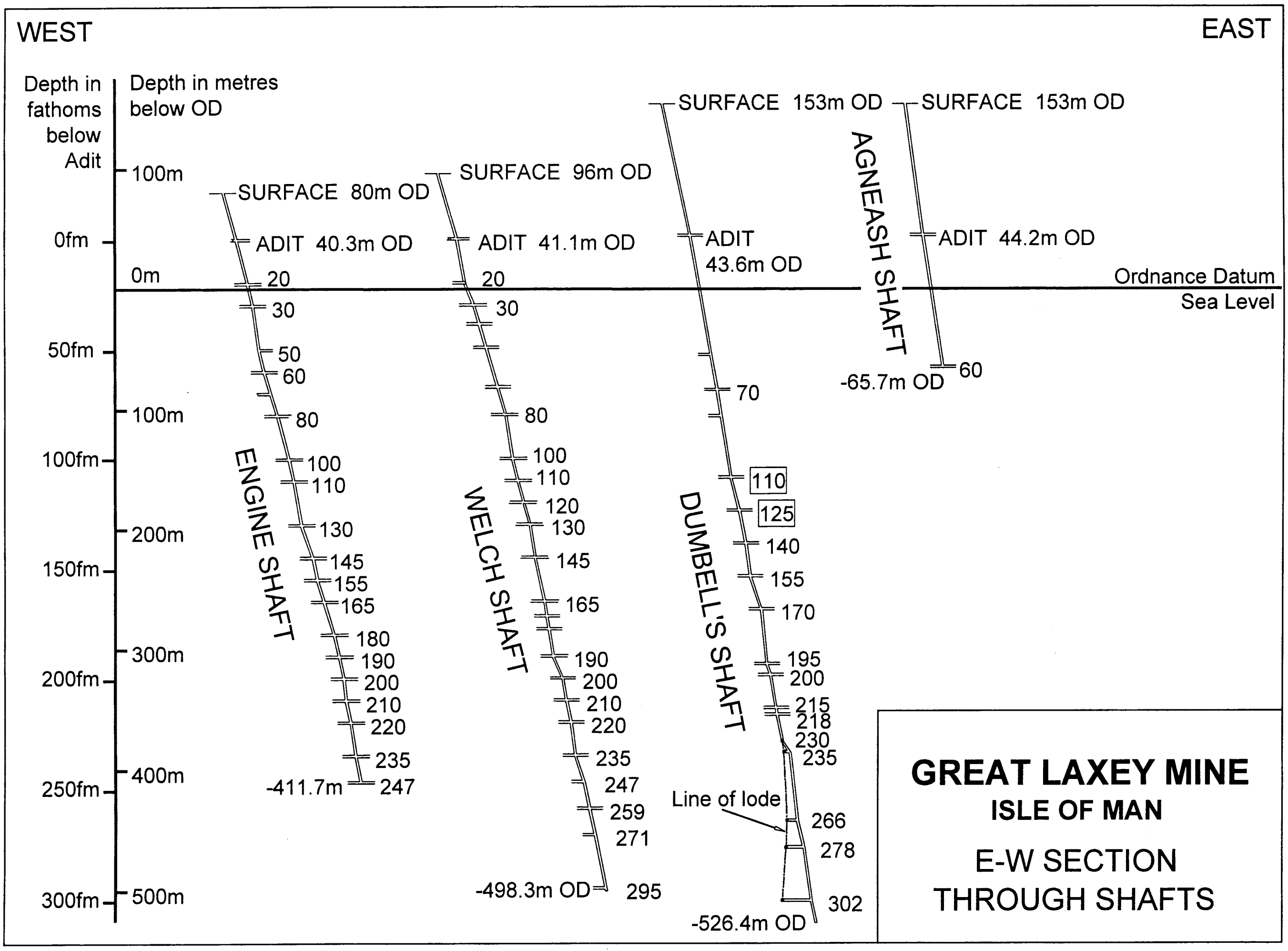

Fig. 6. Profiles of the inclined shafts, with levels indicated (simplified diagram after Jespersen's, 1970, Figure 193). The levels off the shafts are shown as though they were in an E-W plane whereas they are in fact along the N-S trend of the lode. The 1986 survey gave altitudes for some locations which differ from Jespersen's: Engine Shaft surface 81.53m O.D.; Engine Shaft at adit 39.97m O.D.; Welsh Shaft Surface 101.30m O.D.; Welsh Shaft at adit 42.61m O.D. Depths shown in fathoms (1 fathom = 1.83m).

levels seem to show no such displacement. Without further details it is not possible to say if this was a slide in the traditional sense. In spite of old miners' rumours of a slide terminating the vein at the northern limits of the mine, the 1971 exploration party found only a forefield where work was abandoned (Richards and Atherton, 1971). The 1982 exploration was stopped short of this by a roof fall. Before the modern practice of drilling inclined boreholes out from the forefield when the vein is lost, the miners' usual method of finding displaced veins was to drive cross-cuts out along faults but this was apparently not tried at the northern limit of the mine.

Microgranite Dykes. At least two porphyritic microgranite dykes are known to have crossed the lode without apparently affecting its ore content (Lamplugh, 1903). Neither the position nor the orientation of these dykes was recorded on the mine plan. However, at the surface a dyke in Glen Agneash was said to be up to 6m wide (Lamplugh, 1903) though it has not been located in the present study. The dykes were almost certainly offshoots from the Dhoon granite which lies more than a kilometre to the east. Both dykes and granite were emplaced before the Lode, demonstrating its late or post-Caledonian age. Lamplugh (1903) also noted that the Lode cuts across some "older greenstone" dykes (of probable Ordovician age) in its southern section, though again the position was not recorded on the plans.

The Search for Extensions of the Lode. It was logical for the miners to project the line of the Laxey Lode both to north and south to find extensions of ore-bearing ground. The south side of the Laxey valley failed to reveal anything of note. Nothing is known of the New Trial Shaft shown on Jespersen's plan (Fig. 5). To the north, the Lode trends beneath the Slieau Lhean ridge but a high level trial in Glen Ray failed to find anything of significance (Fig. 3).

In the Cornaa Valley, 3km north of Agneash, the North Laxey and Glencherry Mines provide some possible evidence of extensions of the Laxey Lode (Mackay and Schnellmann, 1963). These mines were some 2km north of the end of the main adit. The North Laxey Mine (SC 428 889) worked an almost north-south lode to the east of the projected line of the Laxey Lode, though they may have been linked if some curvature or offset by faulting is taken into account. In contrast to the high sphalerite content of the Laxey Lode, the North Laxey Mine yielded almost exclusively galena with baryte and pyrite becoming more common in the deeper levels. Also contrasting with the Laxey Lode, the vein at North Laxey dipped westwards. The North Laxey Mine was worked to a depth of about 300m though it was never profitable.

Some 500m to the east of the North Laxey Mine, lower down the Cornaa Valley, the Glencherry Mine (SC 433 892) could have been linked with the Laxey Lode provided that substantial allowances for undetected offsets are made. It produced only minor quantities of galena. The East Snaefell Mines (SC 424 888) were located farther west up the Cornaa Valley, lying to the west of the projected line of the Laxey Lode; they were little more than trials as they yielded no significant ore. Lamplugh (1903) made only brief comments on the ore deposits of the Cornaa Valley, but Mackay and Schnellmann (1963) gave details of shaft depths and levels taken from archives in the Manx Museum. The limited accessible levels and other mining relics were described by Pearce and Rose (1979).

Any serious attempt in future to find an extension of the Laxey Lode or parallel veins should involve a programme of diamond drilling of inclined boreholes following re-mapping and structural analysis.

Comparisons with Foxdale. Whilst the Laxey Lode has some similarities to the other large ore body on the Isle of Man at Foxdale, there are also some marked contrasts. The vein at Laxey trends almost north-south whilst that at Foxdale trends east-west. The Foxdale Lode is almost vertical and has been followed deep into the granite whereas the Laxey Lode is steeply inclined and no evidence has been found that the vein penetrated the nearby Dhoon granite at depth. The dominant sulphide at Laxey was sphalerite whereas at Foxdale it was galena. Further research on the Foxdale Lode is required to determine a better comparison with the Laxey Lode.

Origin and Genesis of the Lode

Isotope Studies. Ages of wall-rock and fault gouge alteration based on the K-Ar method have been determined as episodic at 310-320Ma, 285Ma and 250Ma (Ineson and Mitchell, 1979). These ages suggest mid to late Carboniferous dates for mineralization. Preliminary studies by Crowley and Bottrell (1997) show that Pb isotope ratios are compatible with a Carboniferous mudstone source, with two episodes of fluid migration at 300-280Ma and 210-190Ma (i.e. late Carboniferous and late Triassic/early Jurassic). Sulphur and oxygen isotope data suggest a rather wide spread of temperatures of mineralization from 200°C down to 80°C, though the latter may be due to bacterial sulphate reduction associated with the introduction of sulphate-rich fluids derived from sea water (Crowley and Bottrell, 1997). Indeed the presence of baryte late in the mineralization sequence suggests the occurrence of oxygenated fluids at shallow depths.

Metallogenesis. The geochemical processes by which the metalliferous ores of the Laxey Lode were derived, transported and emplaced have not been mentioned in previous literature other than brief comments by Davidson and Bowie (1951) relating to the uraniferous thucholite and in the preliminary isotope studies by Crowley and Bottrell (1997). The general process may, however, be expected to be comparable to that which operated in the Pennines (Ixer and Vaughan, 1993). On geochemical grounds, these ores appear not to have been derived from granites; instead a process of metal release from the clay minerals of mudrocks during lithification is regarded as more likely. As the host rocks for the Laxey lode are "slates" of the Manx Group it might seem logical to regard these as the source, but the emplacement of the lode is considerably later than the folding, metamorphism and the intrusion of the microgranites, so another group of source rocks must be sought. Carboniferous mudrocks provide a possible solution to the problem. These presently lie beneath Permo-Triassic formations on the floor of the Irish Sea, but may well have extended high on to the Manx massif in Carboniferous and early Mesozoic times (Jackson *et al.* 1994; Chadwick *et al.* 1994). The sporadic occurrence of uraniferous hydrocarbons hints at a former cover of Carboniferous rocks (Parnell, 1988). The Eubonia-Lagman fault system which forms the western boundary to the East Irish Sea basin, roughly parallel to the east coast of the Isle of Man (Jackson *et al.* 1994), throws the Triassic down to the east by hundreds of metres, so that in pre-faulting times the strata now forming the floor of the basin would have been much higher in relation to the Manx massif than they are now. The Laxey fracture could thus be a pre-cursor, sub-parallel step fault related to the Eubonia-Lagman fault system. Though the Laxey fracture probably originated from extensional movements in late Carboniferous times, subsequent compression of Carboniferous mudrocks during later Hercynian movements would have expelled formation water containing dissolved metal ions derived from the recrystallization of the clay minerals. On reaching a favourable site, such as the Laxey fracture, where temperatures were lower or where suitable reactions could take place, the ions could come out of solution and combine to form the ore and gangue minerals. Catalysts such as hydrocarbons might have facilitated solution in the source rocks, and a change in physico-chemical conditions would assist precipitation at the depositional stage.

If the source of the metal ions was an argillaceous facies of Carboniferous age offshore beneath the Irish Sea, it raises problems concerning the hydraulics of the route by which the ore fluid moved from the Carboniferous beneath the Irish Sea floor into a fissure system in the Manx slate massif. Recent apatite fission track studies (Chadwick *et al.* 1994; Crowley and Bottrell, 1997) suggest that some 2000-3000m of Mesozoic cover was eroded from northwest England in Cenozoic times, so that a considerable part of this cover may have lain across the Manx massif. Post-Triassic uplift of the Manx massif is indicated by the Eubonia-Lagman fault system bounding the East Irish Sea Triassic basin, so a former extension of Carboniferous strata onto the massif is a distinct possibility and fluid migration into rocks formerly covering the massif becomes feasible. Such migration could be due to a combination of dewatering of the mudrocks, tectonic stresses and thermal gradients. However, until more is known of the Carboniferous rocks beneath the Permo-Trias in the Irish Sea, this can be no more than an attractive hypothesis.

With a mid to late Carboniferous date inferred for mineralization, it is perhaps surprising that no mineral veins of any consequence are known to be hosted in the Carboniferous Limestone of the south of the Isle of Man. Only minor veinlets of galena, sphalerite and dolomite a few millimetres wide have been found. Too little is known of the concealed Carboniferous Limestone beneath the Pleistocene deposits of the north of the Isle of Man for any comment to be made.

Conclusions

The Laxey Lode trends roughly north-south and cuts obliquely across the strike of the Manx Group. The Lode is inclined steeply to the east. Its position hints that it originated as a sub-parallel splay from the Eubonia-Lagman fault system bounding the East Irish Sea Basin. Mackay and Schnellmann's (1963) suggestion that the anticline crossed by the Laxey Lode may have controlled the site of ore deposition is as yet unproven.

Mineralization was later than the folding and metamorphism of the Manx Group and later than the emplacement of the Caledonian granites in early Devonian times (374±4 million years; Brown *et al.* 1968). Isotopic data suggest episodic mineralization in mid to late Carboniferous times, whilst structural considerations imply late Carboniferous rather than middle. These dates agree broadly with mineralization events in the North Pennines. There was a possible later phase of mineralization in late Triassic/early Jurassic times.

A source for the mineralizing fluids in argillaceous Carboniferous rocks extending from the East Irish Sea basin onto the Manx massif is a distinct possibility.

More research is needed to determine the structural history as well as details of ore textures and paragenesis. Regrettably no fluid inclusion studies are known to have been carried out on Laxey minerals so that no estimate of the temperature of crystallization is possible. To test the above hypothesis of ore genesis requires more accurate knowledge of the date of ore deposition than is permitted by the limited isotopic data available at present. It would also be necessary to assess the temperature and stress histories of both the Manx Group and of the surrounding Carboniferous rocks.

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