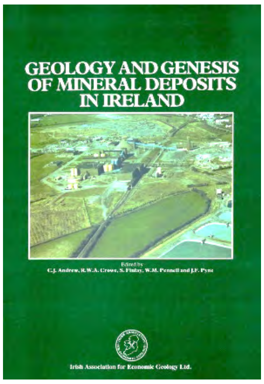

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A review of vein mineralization in SW County Cork, Ireland.

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Abstract

The extent and style of Cu, Ba, Mn and Fe vein mineralization in SW County Cork is described by reference to seven deposits. Recently published radiometric data and the structural setting of the veins indicate a late syntectonic (Hercynian) mineralizing event. The veins occur at many stratigraphic levels within the 2-7km of the Frasnian-Fammenian fluvial red-bed fill of the Munster Basin, and extend upwards into the succeeding Strunian and Courceyan transgressive marine sediments. Geographically, mineralized veins are most frequent in the southwestern quadrant of the Munster Basin, and have been historically regarded as forming a distinct 'Mining District', although production has been small-scale and sporadic. The area of distribution of these veins is only partially coincident with the area of late Fammenian (?) and syn-to post-tectonic volcanism or with the main concentration of stratiform copper mineralization, and is set apart from areas where negative gravity anomalies have been interpreted as due to granitic bodies at depth. Limited lithogeochemical data hints at possible depletion of Cu and Ba in deeper fine-grained Munster Basin sediments. The volume of sediment in the Munster Basin axis would be adequate as a source of mineralizing brines for internal vein systems.

Introduction

The West Carbery mining district and the Bearhaven mines (Cole, 1922) covers an extensive area of SW County Cork long known for its copper, barite and manganese mineralization. The intensive exploration of the area during the early years of the last century was largely due to the enthusiasm of Colonel H. Hall, who was sent to Ireland to suppress the 1798 rebellion at the head of a regiment drawn from the Cornish mining areas (Hall, 1883). His early mining activities encouraged interest among the landlords (Reilly, 1980) and by 1824 Richard Griffith was promoting the area to the Government's Select Committee for the Valuation Survey. Long lists of mines, trials and showings had been initially compiled by Griffith (1861), and Kinahan (1861 and 1889) and these were later added to by Hallissey (1923), Duffy (1932), and more recently have been documented by Snodin (1972). The stratabound syngenetic nature of the 'Copper Bed' mineralization was recognized from the beginning (Griffith 1821 and 1854; Kinahan, 1861) and a model involving lateral secretion was proposed for the vein type mineralization.

The lithostratigraphy of the area has received considerable attention in the last decade; for reference lists and summaries see Graham (1983) and Naylor et al. (1983). There is little regional lithogeochemical or isotopic data. Current academic projects (Sanderson, 1985; Cooper et al., 1985) should, however, provide a basis for regional evaluation of the structural setting of mineralization.

The West Carbery mining district is located in the half-graben shaped Munster Basin (Naylor and Jones, 1967). The Upper Devonian basin-fill is exposed in a series of ENE-trending anticlines with wavelengths of several tens of kilometres which follow the peninsulas, while the Carboniferous rocks occupy the lower ground in the synclinal valleys and rias.

The Frasnian-Fammenian red-beds (Graham, 1983) consist of 2-7km of fluvial sediments which coarsen and thin towards the basin margins, and indicated by the isopachytes (Fig. 2). The Carbery mining district is near the southern margin where a thickness of more than 1.1km of green sandstone-dominant fluvial channel facies (Sherkin Formation) is overlain by 0.7-1.4km of purple floodplain mudrocks (Castlehaven Formation). The Bearhaven mines, further west, are closer to the basin axis. Various estimates suggest that here more than 1.5km of purple distal floodplain mudrock (Ballydonegan Slate) are overlain by 1.2 – 3.6km of proximal floodplain sandstones (Allihies Sandstones) and by a further 0.3-1.5km of distal floodplain facies mudrocks. The basin fill is succeeded across most of the district by a persistent grey-green fluvial coastal plain sandstone facies (Toe Head Formation) about 0.5km thick, which heralds the Strunian marine transgression. This transgression was initiated in the *LL* miospore subzone along the south coast but did not reach the Bearhaven mines area until *LN* subzone times (Fig 2). About 0.5-1.5km of tidally influenced sand-dominant heterolithic marine facies (Old Head Sandstone Formation) and the succeeding mudrock-dominant Kinsale Formation represent this transgression. Within the Carbery district the Upper Courceyan — Visean consists of some 0.6km of clastics with subordinate calcareous mudstones, thin limestones and pyritic dark mudstones (Courtmacsherry and Lispatrick Formations). North of the Cork-Kenmare line (Fig. 1) about 1.8km of shelf and mudbank carbonates accumulated during this interval. Namurian shales and turbiditic sandstones complete the Carboniferous sequence.

At least 42 mineralized veins are known (Fig. 1) so that a description of each can not be attempted here. Instead seven deposits, named in Figure 1, have been selected to illustrate a range of characteristic features. Most have been reinvestigated during recent exploration programmes. Some of this new information has become available in the Geological Survey through a recently introduced scheme for the release of data on surrendered prospecting licences.

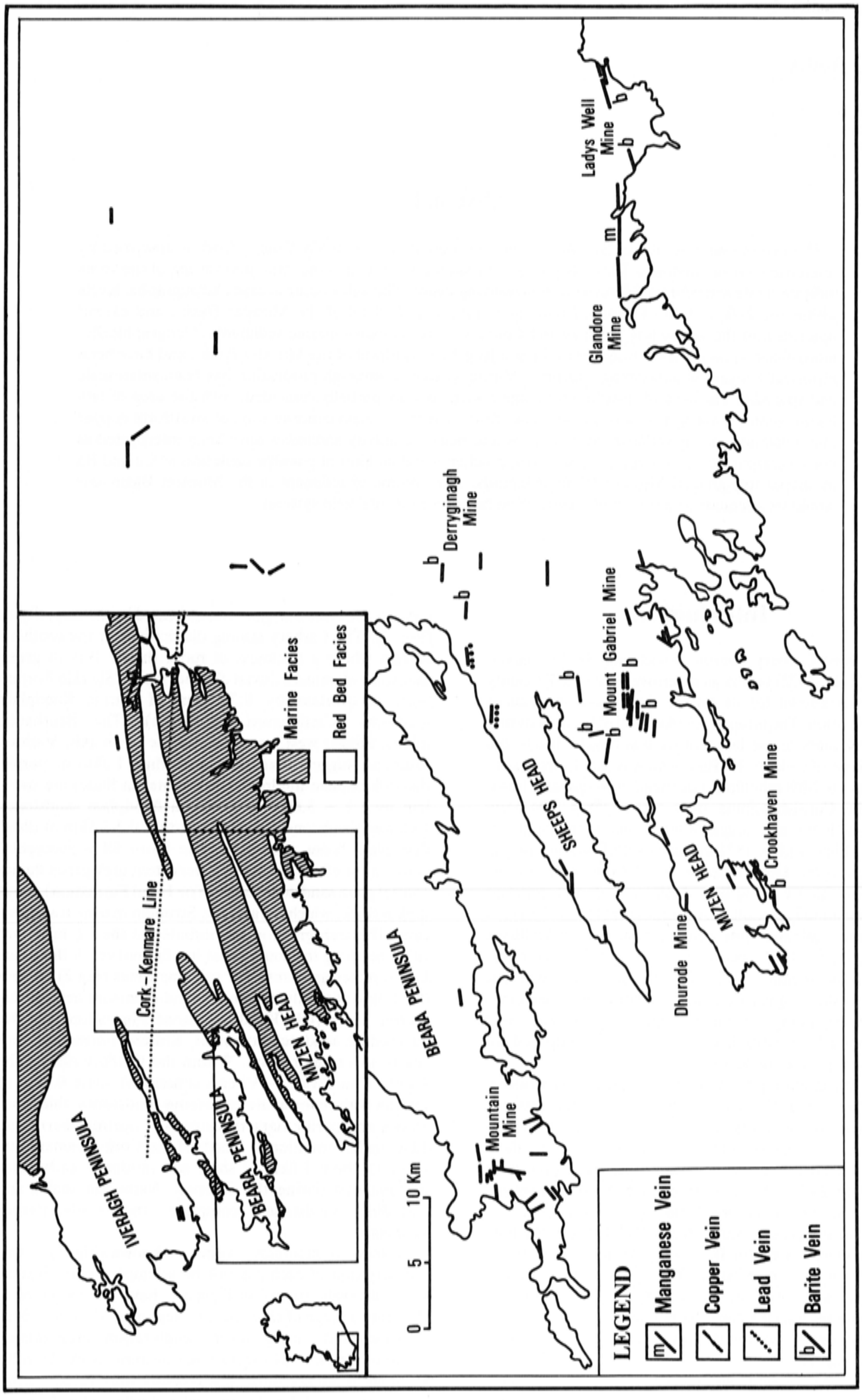

Figure 1 Vein deposits distibution map. Vein size is greatly exaggerated for clarity. Based largely on GSI records and Duffy (1932).

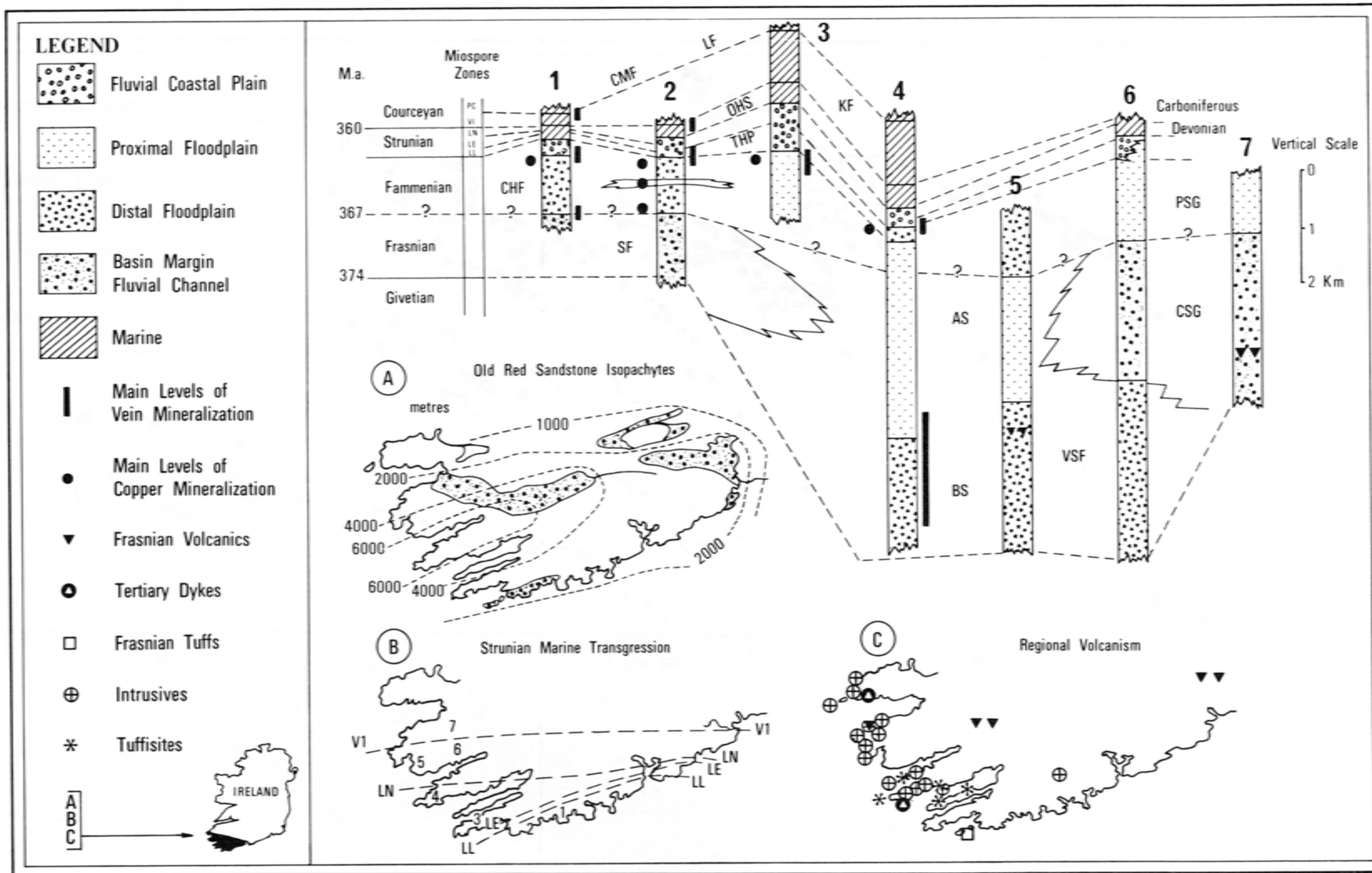

Figure 2 Geological setting of vein mineralization in the Munster Basin. Correlation of successions from (1) Galley Head — Glandore (Reilly and Graham, 1972); (2) Toe Head-Clear Island (Reilly and Graham, 1976); (3) Mizen Head (Naylor, 1975); (4) West Beara (Viswanathiah, 1959 and Sheridan, 1964); (5) West Iveragh (Russell, 1978); (6) Sneem (Capewell, 1957); (7) Lough Guitane (Avison, 1982). Miospore Zone correlation from Higgs and Russell (1981), inset of the Courceyan marine transgression from Clayton and Higgs (1978), facies and isopachytes from Graham (1983). SF=Sherkin Fm. CHF=Castlehaven Fm. THF=Toe Head Fm. OHS=Old Head Sandstone Fm. KF=Kinsale Fm. CMF=Courtmacsherry Fm. LF=Lispatrick Fm. BS=Ballydonegan Slates. AS=Allihies Sandstones.

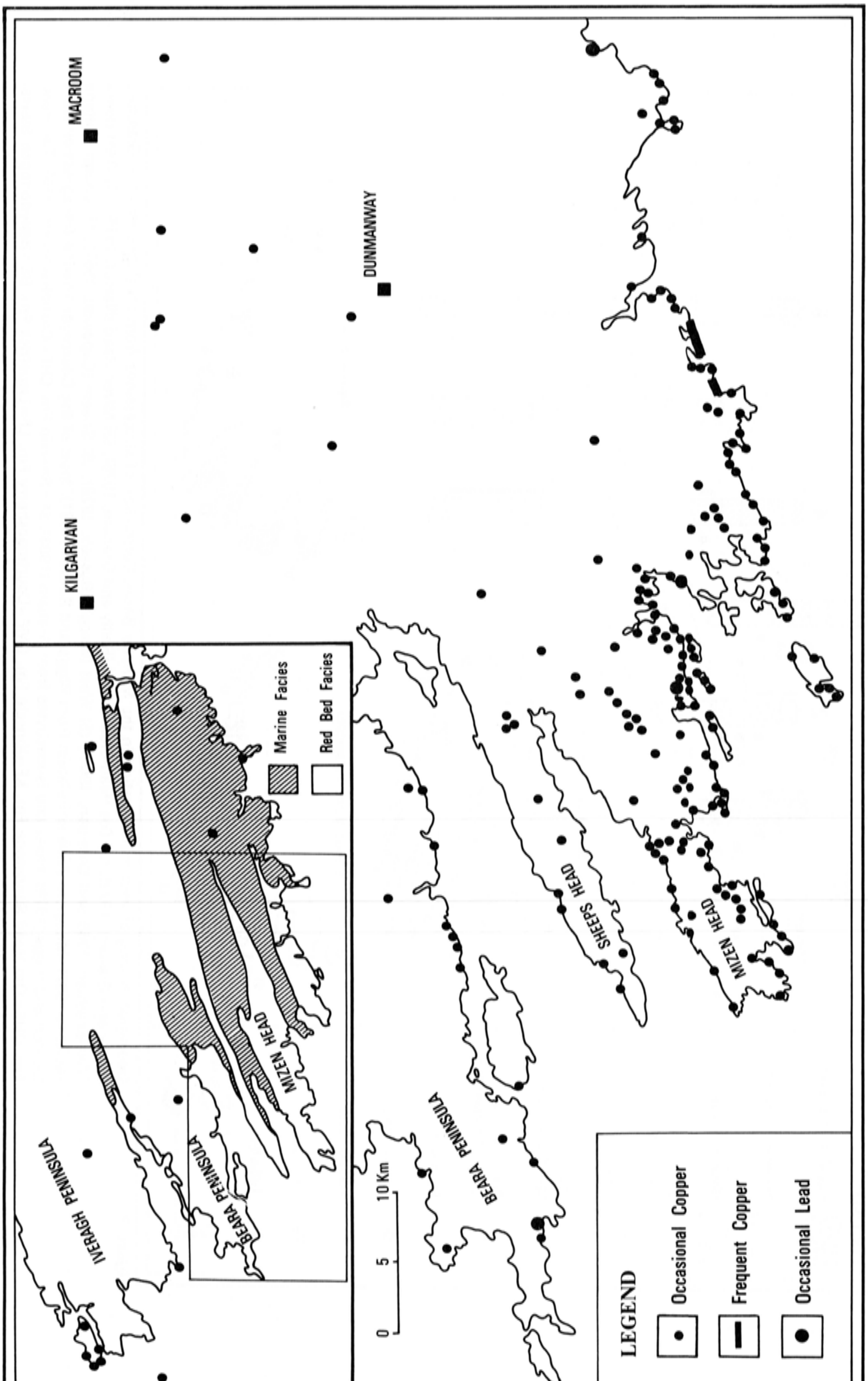

Figure 3 Mineral showings distribution map based largely on GSI records and Duffy (1932.).

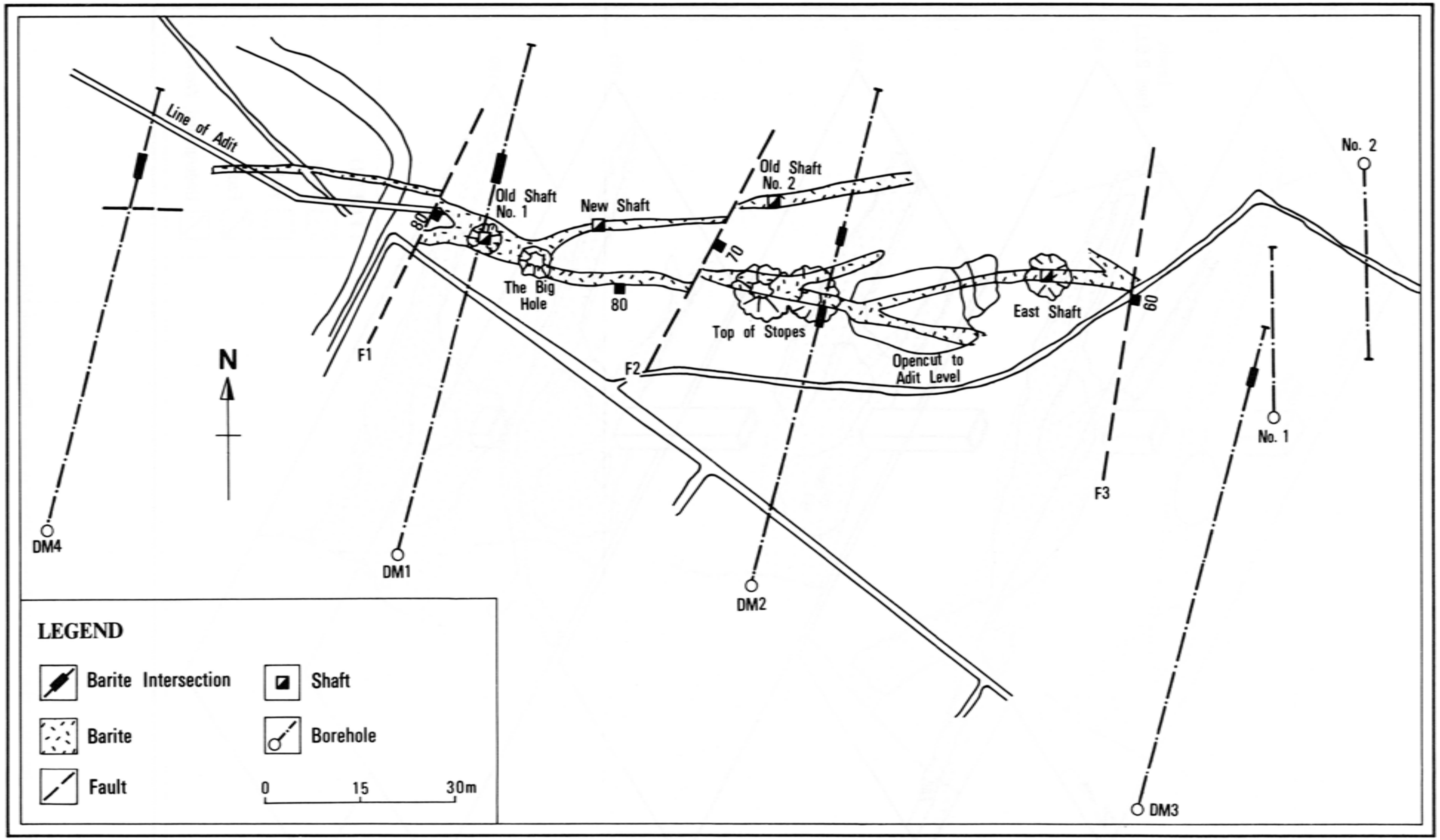

Figure 4 Surface plan of Derryginagh Mine based on a plan by D. H. B. Fitzgerald (1960) with location of additional boreholes by Dresser Minerals Ltd. (Grennan, 1983).

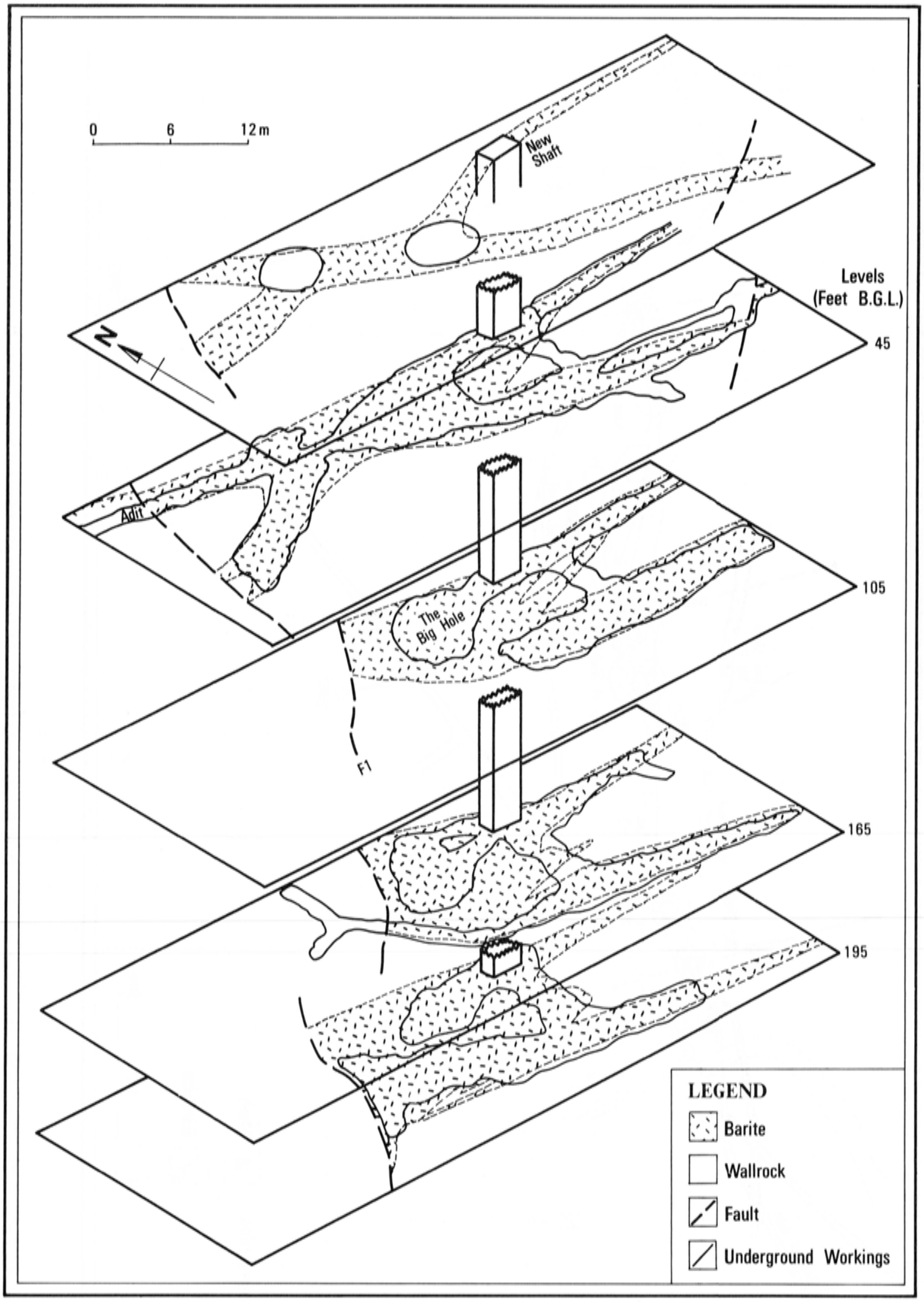

Figure 5 Isometric sketch of the New Shaft workings — Derryginagh Mine.

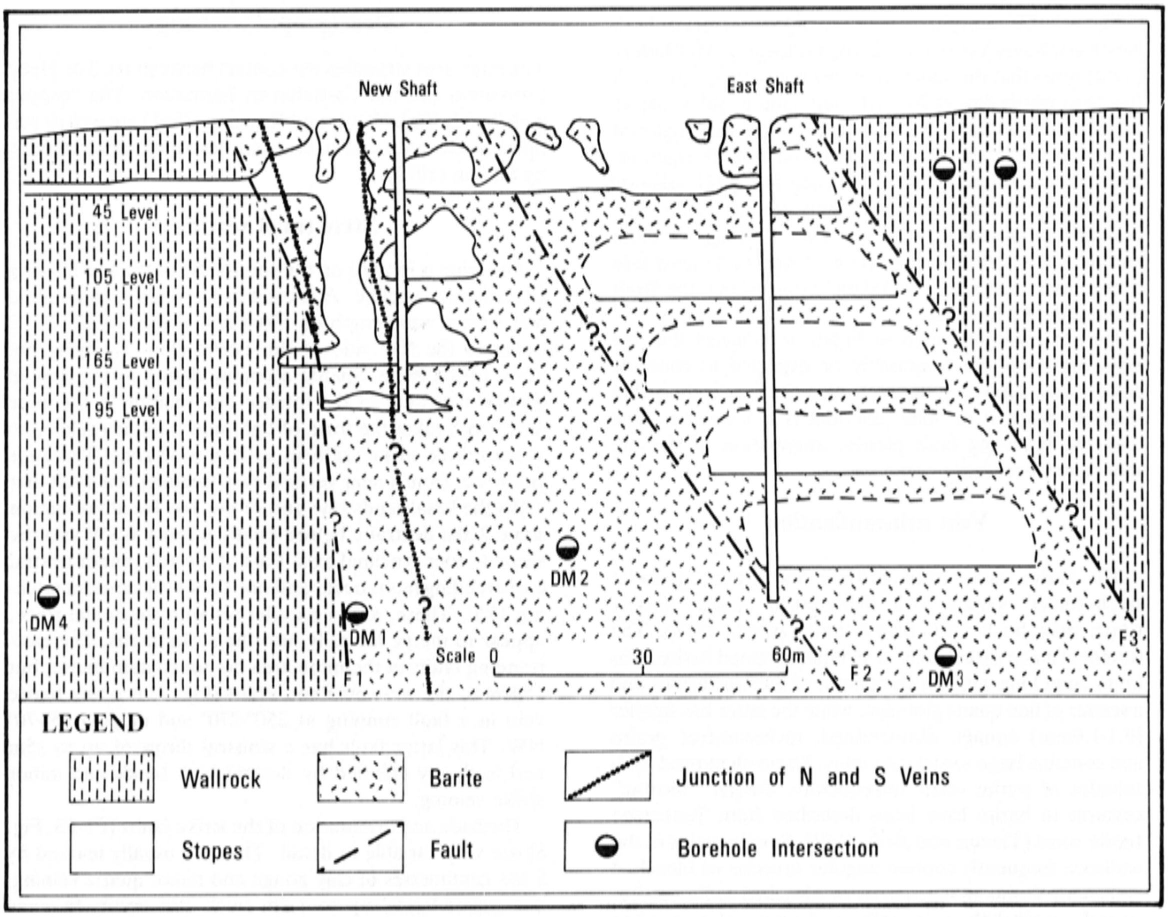

Figure 6 Longitudinal section of Derryginagh Mine with inferred structure and borehole intersections.

Derryginagh Mine

Exploration and development

This barite vein was discovered about 1853 and was in sporadic production up to 1921. Production figures are incomplete and the mine changed ownership frequently, but in all about 35,000t of barite were produced. In 1960 Messrs. D.H.B Fitzgerald and J. F. Lenehan drilled two boreholes (DDH1 and DDH2, Fig. 4) on the presumed eastwardly extension of the vein, and in 1961 they dewatered and re-entered the New Shaft workings. Initial grab samples had given 96-97% $BaSO_4$ for first grade ore, but a 412t bulk sample obtained during deepening the New Shaft from the 165 Level to the 195 Level graded only 88% $BaSO_4$. Beneficiation tests with 30 mesh grinding and heavy mineral separation successfully upgraded 79.8% ore to 96%, and with renewed impetus from Messrs. F. N. S. Hughes and P. J. Foley the deeper level was driven 28m west. Market and beneficiation problems led to closure in 1968. During 1973 Industrial Minerals and Chemicals Ltd. again dewatered the mine for sampling, and finally, in 1981, Dresser Minerals Ltd. drilled a further 4 holes (DM1-DM4) to intersect the lode at depth.

Stratigraphic setting

The vein is located near the top of the Old Red Sandstone sequence. Pale grey, grey-green or grey-purple siltstones and fine sandstones are found in both hangingwall and footwall of the New Shaft workings.

Structural setting

The vein cuts nearly vertically-dipping beds on the northern limb of the Sheeps Head Anticline at an angle of about 15° to strike of both bedding and cleavage. The marine facies contact which is 10m north of the footwall in DM1 is offset more than 500m by a complex east-trending dextral tear-fault zone in which the veins are developed.

Description of veins

The general form of the branching vein system at the surface is shown in Figure 4, based on the mine plan by D. H. B. Fitzgerald (1963). The overall trend is 260°-280° and the veins dip at 80°-88° to the south. Three possible NE cross faults (F1-F3) divide the vein into four sections. The 1960-1973 activity was confined to the New Shaft workings where two subparallel veins join to form a near vertical pipe about 12m by 10.5m on the 195 Level. The shape of the pipe in depth is indicated by an isometric drawing in Figure 5. In the adit the North Lode stops abruptly and is stoped upwards for 9m. A wedge of wallrock separates this from the South Lode, the west end of which also appears to be cut out. Only one significant vein was cut by the adit and by DM1. On the 165 Level the South Lode drive west stops abruptly against a near vertical NE-trending surface. This corresponds to a similar cut-off on the 195 Level where an offshoot turns south along this surface (Fig. 4). These intersections are interpreted as representing a rather irregular single fault surface (F1). The eastern end of this section is terminated against a

NNE fault (F2) thought by Fitzgerald (1963) to offset both North and South Lodes up to 2.4m northwards. McCluskey (1962) notes that the Lodes show pinching as they approach this fault which dips at 70° ESE flattening to 60° at the 45 Level (Allen, 1918). A third fault (F3) in old workings east of the East Shaft was reputed to dip at 60° ESE (Fitzgerald, 1963). The absence of the South Lode in DDH1 suggests that this fault also offsets or terminates the Lode. The cessation of stoping in the East Shaft workings at 100m and the shift of stopes from the west side to the east side of the Shaft (Allen, 1918) is taken to suggest that the Shaft entered the F2 footwall.

The structure suggested in Figure 6 indicates that the main oreshoots can reasonably be expected to continue downwards. However, there is also the implication that since the pitch of the lode junctions is at a steeper angle than the bounding fault planes, attenuation of the ore shoots may eventually occur.

Vein mineralization

The barite varies from a white first grade "granular saccharoidal" variety to a fine-grained opaque variety which may be heavily discoloured (Allen, 1918). The former is made up of single or twinned strained barite laths up to 5mm long with a high content of fluid inclusions and a scatter of fine quartz globules, while the latter has smaller (0.1-1.0mm) equant, non-strained, inclusion-free grains and contains large specularite laths. Strain-shadowed pyritohedra of pyrite occur infrequently. Similar "mortar" textures in barite have been described from Tennessee barite veins (Tieman and Koff, 1983). Smaller veins in the wallrock frequently contain angular breccias of bleached sediment. Trains of specularite or bleached sediment frequently parallel the vein walls, and assay values tend to improve towards the vein centres.

Wall rock alteration

The wallrock adjacent to the vein is frequently strongly bleached and commonly contains anastomosing veinlets of quartz/barite. Slight bleaching may occur for up to 20m (e.g. DM2, hanging-wall) but at other contacts purple sediments occur adjacent to the contact (e.g. DM2, footwall). Bleaching is also associated with minor veins in the wallrock so that alternating colour bands can occur.

Surface alteration

At all levels in the mine there are vugs in ore which may once have been specularite-filled, but now contain only partial infills of iron hydroxides. Reddening and discolouration of barite adjacent to joints has also been observed at adit level.

Crookhaven Mine

Exploration and development

Between 1844 and 1884 the Crookhaven Mine on the coast SE of Crookhaven village (Fig. 7) was intermittently active although copper ore sales appear to have been negligible. In 1969 following a regional and detailed geochemical programme (Keele, 1964) Irish Metal Mining Ltd. drilled two southerly inclined boreholes (69-C-1 and 69-C-2) parallel to the old workings. These old workings are described in an abandoned mine plan of 1853.

Stratigraphic setting

The mine area straddles the contact between the Toe Head Formation and the Castlehaven Formation. The "copper beds" of Griffith (1854) and Kinahan (1861) are well developed in this area and have been described more recently by Snodin (1972).

Structural setting

The mine is located on the south limb of the south facing Crookhaven syncline. A second order WSW-trending fold pair with a wavelength of 100m and plunge of 12°-22° E traverses the NW side of the Island (Fig. 7), dying out north of the mine. Spatial accommodation to this may in part be the cause of the intense deformation in the mine area which takes the form of tight minor folding related to at least three strike faults in an 80m wide zone. This zone splays out from a near vertical east-trending tear-fault that shifts the basal sandstone unit of the Toe Head Formation some 220m dextrally before finally turning WSW into the second order synclinal axis. East of the adit, minor dextral east-trending faults occur and one shows slickensides pitching 18°E. These, and a parallel set with sinusoidal trace, appear to merge laterally into the strike faults. The east-trending faults in the mine area do not contain barite, but 1500m to the west on Reen Point (Fig. 7) is a thin barite vein in a fault running at 250°-270° and dipping 65°-70° NW. This latter fault has a sinistral throw of up to 15m and is clearly affected by dextral kink bands and minor strike veining.

The hade and orientation of the strike faults (F1-F3, Fig. 8) are very variable in detail. They are usually marked by a few centimetres of clay gouge and minor quartz veining, but quartz 'reefs' up to 1.2m thick also occur. In some instances where these faults approach vertical, bedding is clearly truncated and reverse movement is evident. Rotation between fault-bounded blocks changes or reverses drag fold plunges across strike and across E-trending fault sets. These relations, the lack of evidence for refolding of cleavage, and the folding of related veinlets are all suggestive of a late syntectonic age for the Crookhaven mineralized structures.

Description of main veins

The focus of mining activity has been the Champion Lode which, where it swells at surface to 9m in width, has long been recognized (Duffy, 1932) as a saddle 'reef'. This 'reef' is exposed in an anticlinal core south of F3 near the West Shaft. Some 260m further east the Engine Shaft was also sunk on the F3 Fault Lode. The abandoned mine plan inaccurately indicates that this Lode dipped here at 65° N whereas Thomas (1859) and Jukes (1861) specifically state that the hade was nearly vertical but confirm that it was sunk on for about 80 fathoms (146m). The other important lode was the Gossan Lode which is identified in outcrop as a 1.3m wide interformational calcareous shale breccia (cornstone). This extends along strike for about 1.2km before dying out, and is much reduced in thickness where intersected in 69-C-2 at 82m. Rapid lateral facies changes in the channel sandstones make it difficult to match core and surface beds, so the cross section (Fig. 9) is somewhat speculative. This drilling clearly demonstrates that neither the Gossan Lode nor the tightly folded Purple Ore Lode are strongly mineralized at depth and that the well-developed near surface mineralization reflects strong gash veining in a tectonized zone.

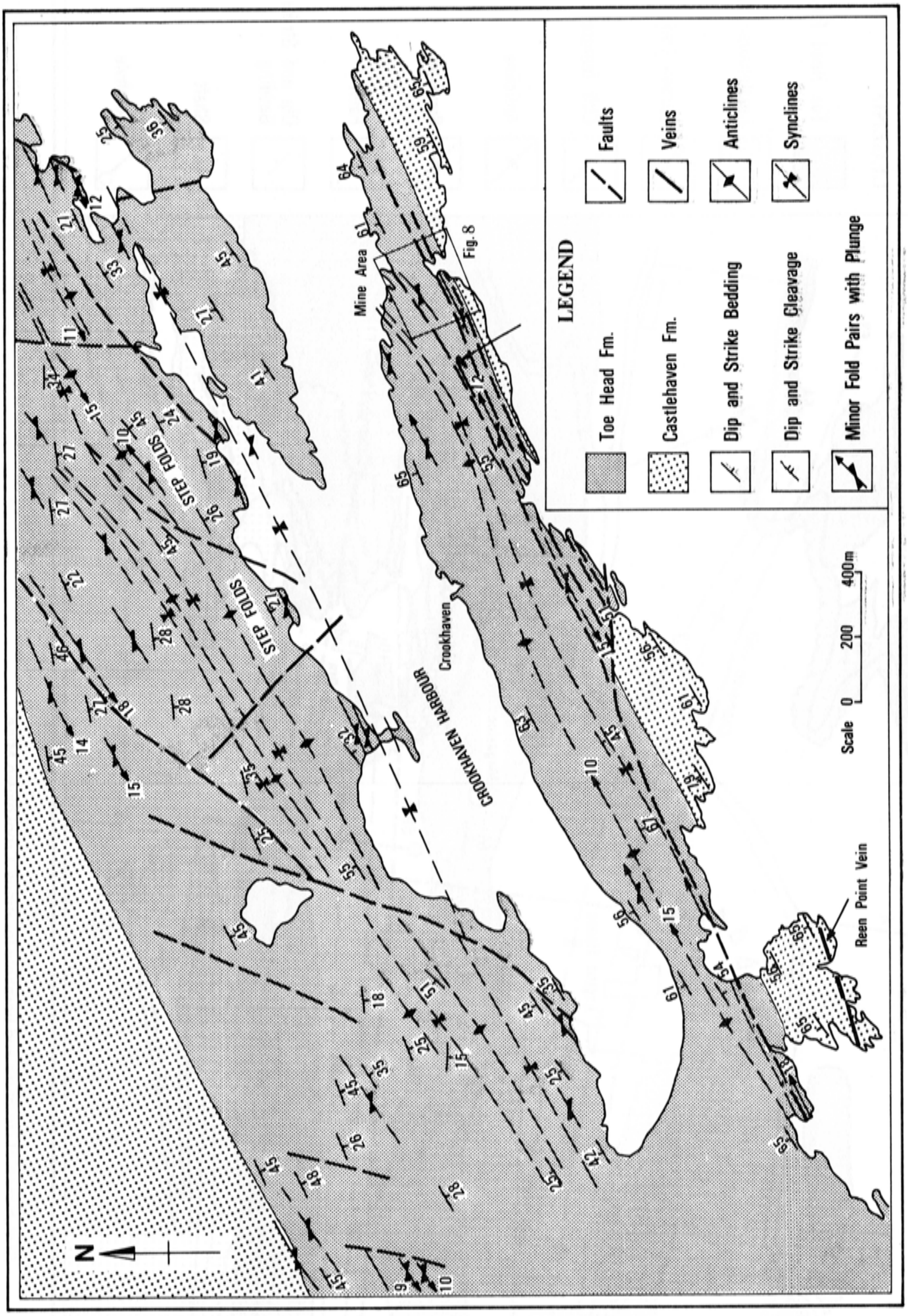

Figure 7 Sketch map showing the geological setting of Crookhaven Mine.

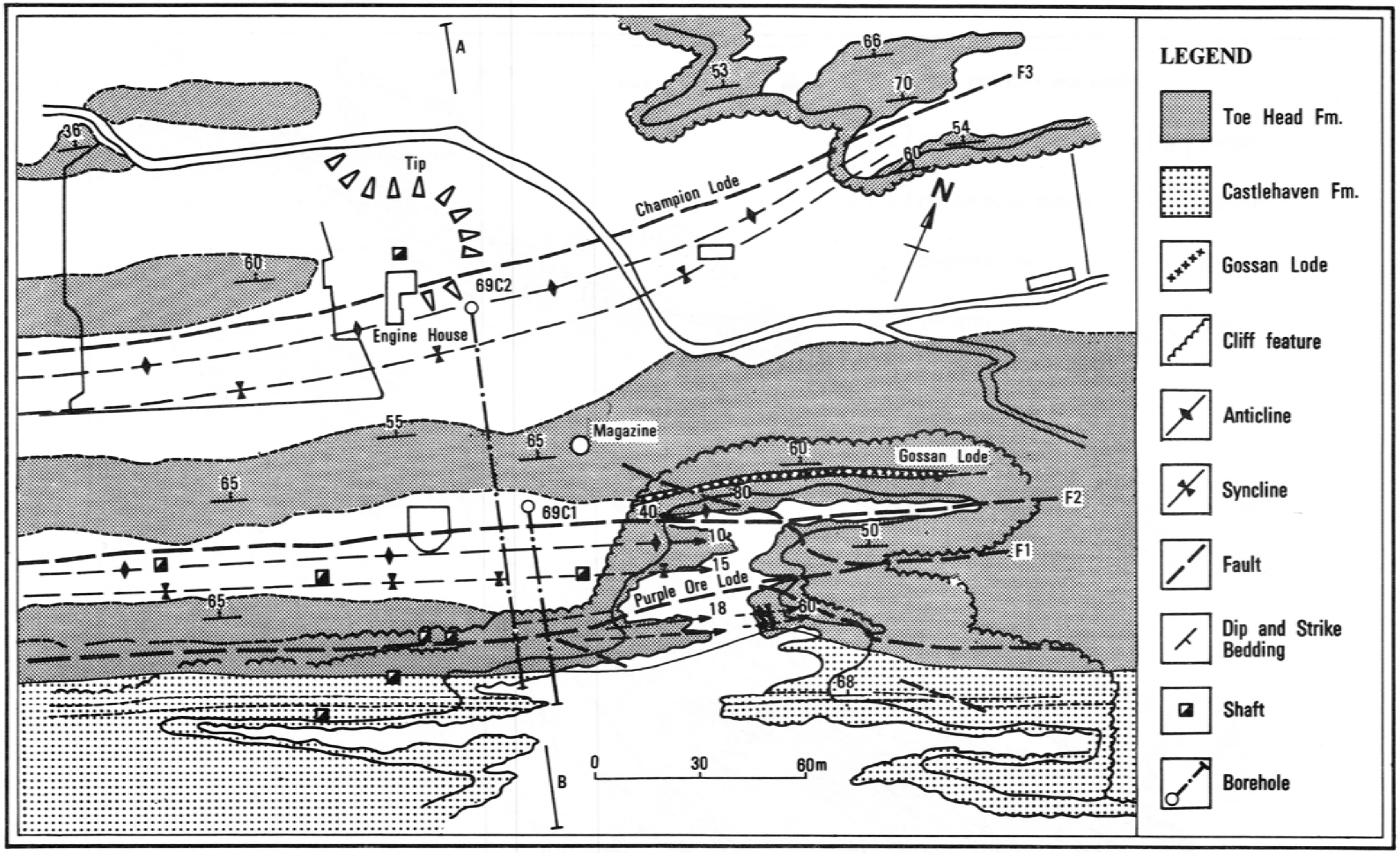

Figure 8 Sketch map of structure and borehole locations, Crookhaven Mine.

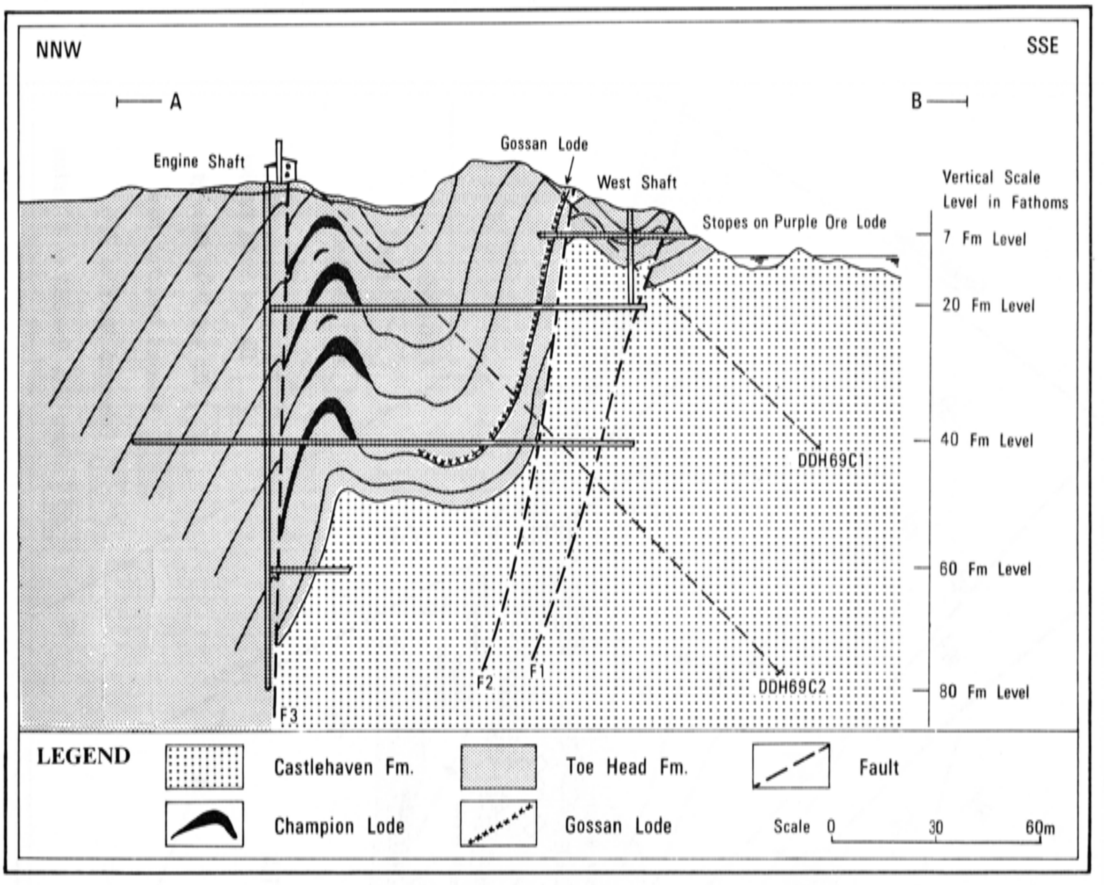

Figure 9 Conjectural cross-section of Crookhaven Mine, based on surface information, Irish Metal Mining Company borehole logs and abandoned mine plan.

Vein mineralization

The main ore raised was from the Purple Ore Lode gash veins and the Gossan Lode which both contain chalcopyrite-bornite-quartz assemblages typical of the copper bed mineralization. The Champion Lode has no record of other than chalcopyrite and lacks the distinctive assemblages of the other major vein deposits (Snodin, 1972). The reference to silver-lead at Crookhaven (Holdsworth, 1858) may have arisen from a reported copper ore analysis with 45 oz/ton Ag (Mining Magazine, 1853 and 1854). Three early assay results for Au range from a trace to 1.5 oz/ton; (Mining Mazagine 1854). The higher value is, interestingly, from a gossan sample, but values may have been inflated for promotional reasons.

Wall rock alteration

Adjacent to the saddle reef there is only minor bleaching and chloritization, and even included wallrock blocks are only slightly affected.

Mountain Mine

Exploration and development

Veins at the western end of the Beara Peninsula (Fig. 1) have been consistently exploited since about 1812 when the malachite-stained lode at Dooneen Mine was identified in the seacliffs (Blenkinsop, 1902). The ubiquitous Col. Hall is credited with encouraging the landowner, Mr. Puxley, to finance development, and the Berehaven Mining Company was formed. In 1865 the Puxley family sold out to the Mining Company of Ireland (Blenkinsop, 1902), but by 1884 increasing depth and falling ore prices led to closure. Exploration and minor production about 1900 (H. G. Blenkinsop) and 1920 (Allihies Copper Mining Co. and British Non-Ferrous Metal Corp.) was short-lived. Production records (O Brien, 1959) indicates a total of 284,500t of 9% concentrate were sold which, taking about 3% for average grade of broken ore (Collins, 1917) implies nearly 1Mt of ore raised. Although there are at least 23 significant vein deposits in this area, the ore was largely from four mines, where the veins were followed in depth. These were Mountain (450m), Kealogue (432m), Caminches (264m) and Dooneen Mines (162m). Between 1956 and 1961 The Emerald Isle Mining Company dewatered Mountain Mine and following an extensive drilling programme defined 1.3Mt of 1.65% Cu below the old workings. The description below is largely based on research projects carried out at that time. (Viswanathia, 1959; Sheridan, 1961; Matthews, 1964; Fletcher, 1969).

Stratigraphic setting

The thickness and sequence of the stratigraphic units at the western end of the Beara Peninsula is uncertain because

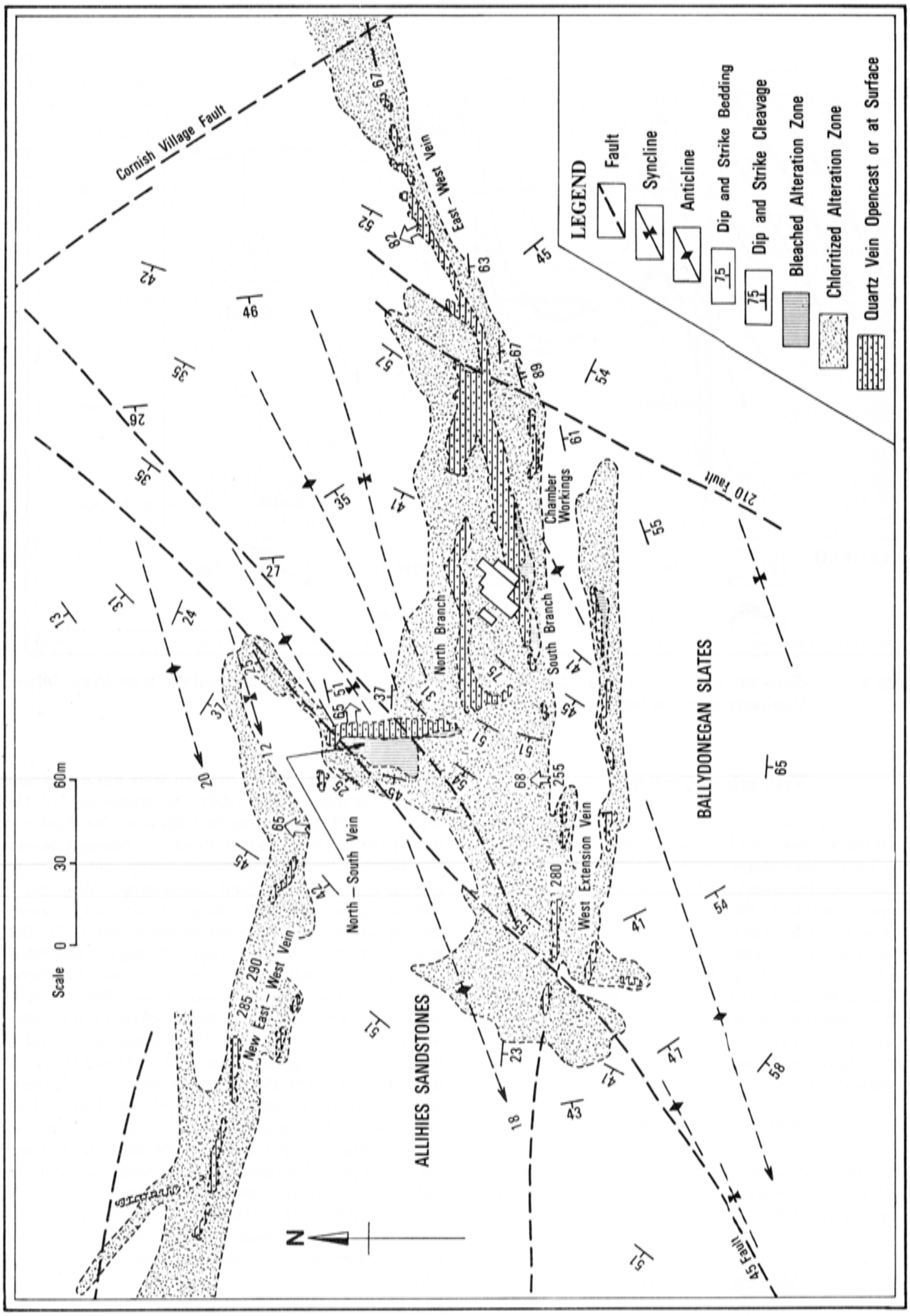

Figure 10 Sketch map of the Mountain Mine Vein at surface based on plans by Sheridan (1960), Matthews (1964), and Fletcher (1969).

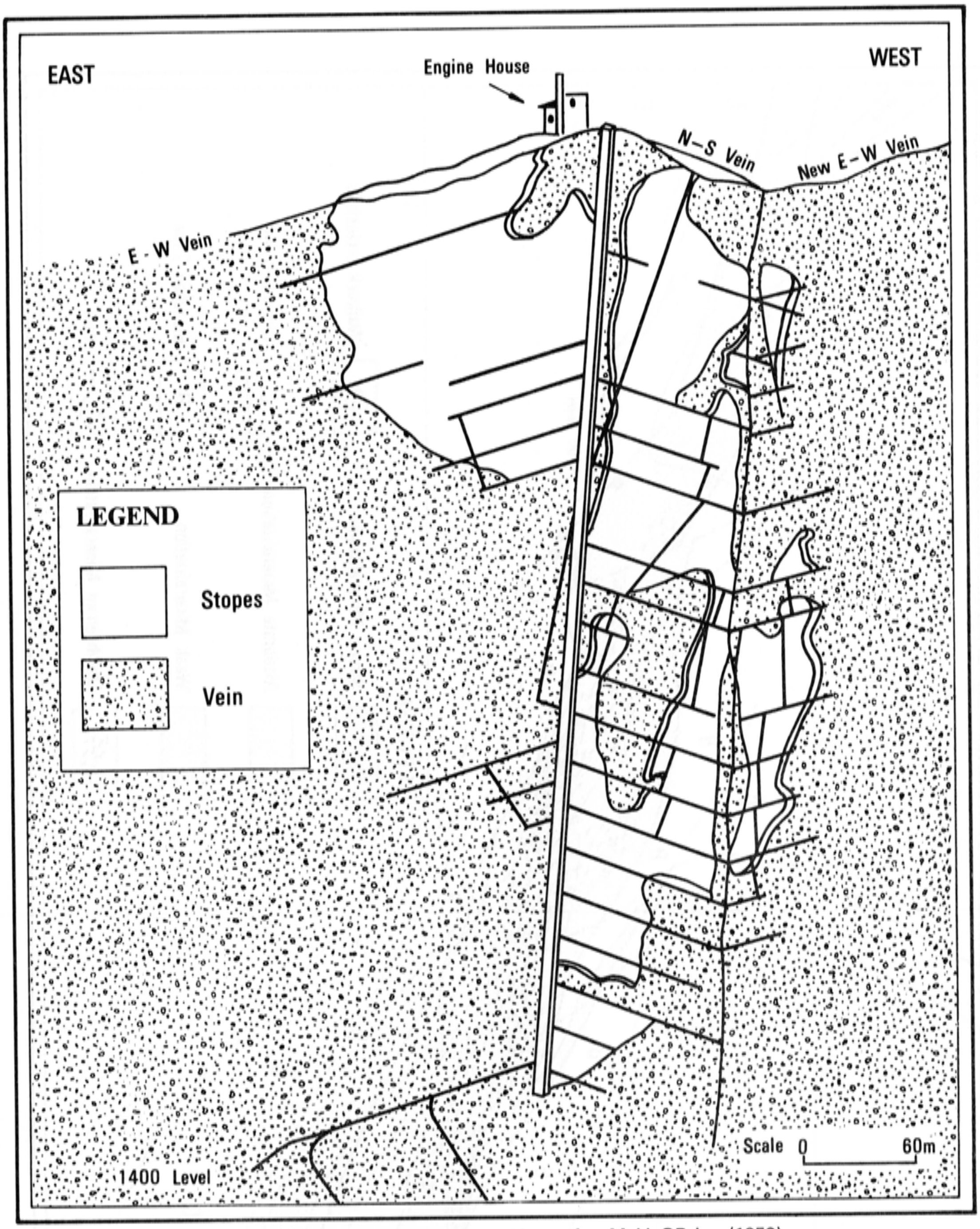

Figure 11 Isometric sketch of Mountain Mine workings after M. V. OBrien (1959).

of the lack of marker units (Coe and Selwood, 1963) and the presence of strong wrench faulting (Capewell, 1957). Viswanathia (1959) and Sheridan (1964) agree that a fault running through Dooneen Mine to Mountain Mine throws Allihies Sandstones (about 1200m thick) against the underlying Ballydonegan Slates (+1500m thick). Matthews (1964) and Fletcher (1969) see this line, in part, as one of facies change with one or two sandstone levels occurring within the Ballydonegan Slates. However, there is general agreement that across the Mountain Mine structure sandstones abut against slates at the surface, this contrast being lost in depth (Fletcher, 1969). Around the coastline numerous microdiorites and trachyte dykes and sills (Boldy, 1956; Viswanathia, 1959) and intrusive tuffs with ultrabasic xenoliths (Coe, 1966) have been recorded, and syenites have been encountered in drilling at Kealogue (Matthews, 1964).

Structural setting

The Beara anticline runs from near Kealogue Mine to Dursey Head (244°) and plunges to the west at 47°±7° (Coe and Selwood, 1963). A matching syncline 5.7km to the north on Cod's Head trends at 246° and plunges west at 30°. The Mountain Mine is situated about half way between these axes where the fairly consistent 55°±15° dips swing

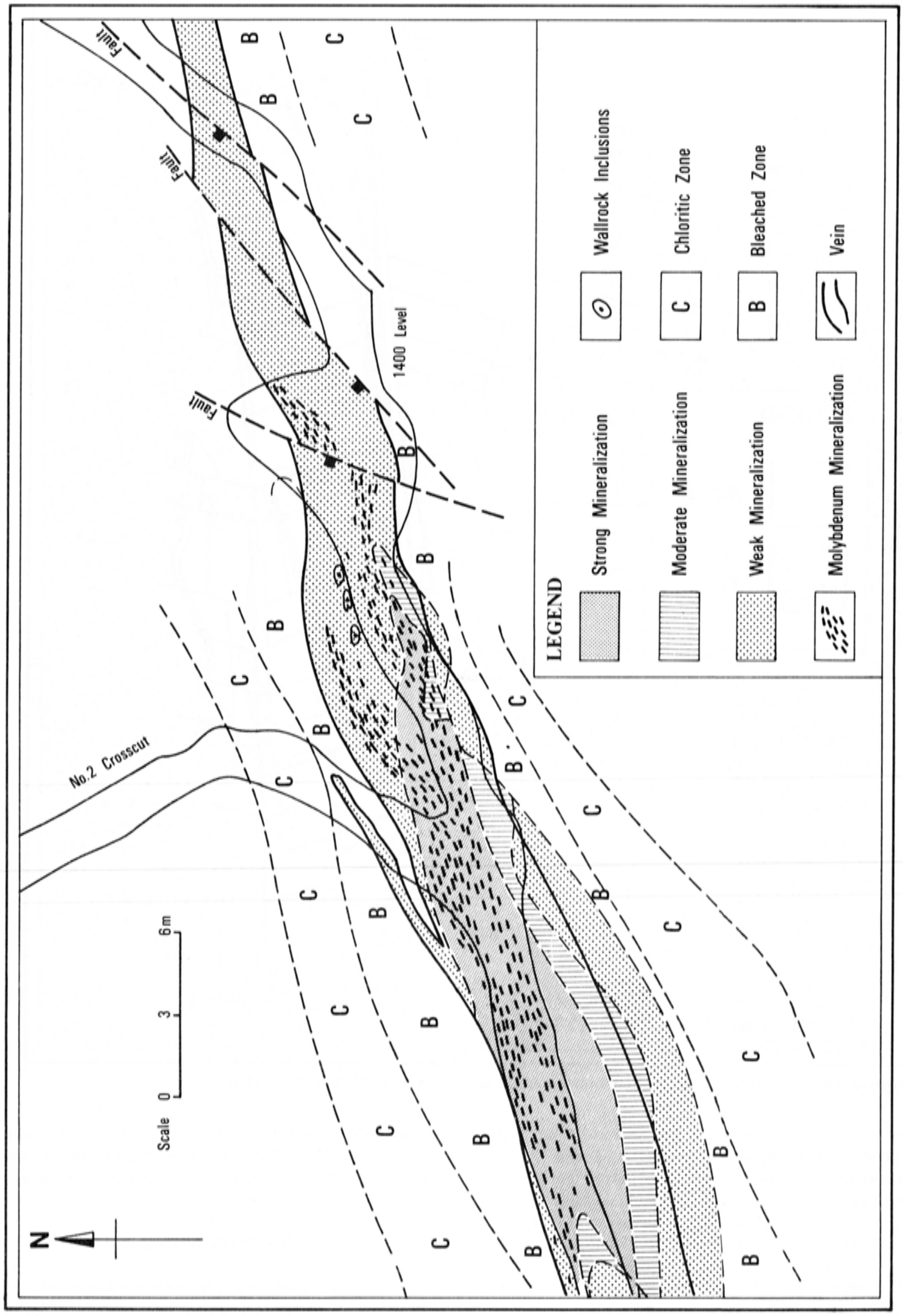

Figure 12 Distribution of mineralization on the 1400 level, no. 2 crosscut after Matthews (1964).

from NNW to NW. Third order open symmetrical folds with wavelengths of 90-150m occur in zones, notably near Mountain and Coom Mines. These may diverge up to 20° from the regional trend and have shallower plunges (2°-20°WSW). Minor asymmetric folding with varied plunges is clearly related to shear/fault zones and complicated by varying response to bed thickness and competence. Penetrative cleavage is close to vertical and axial planar with respect to the major folds (Coe and Selwood, 1963). The quartz veins are locally developed in major faults for lengths of up to 600m and widths of up to 18m. These faults trend ENE and hade 65°-85° northwards. The Illings Feeder and the Cornish Village Fault are the most important of the infrequent NW-trending faults, and both show structures suggesting that they pre-date mineralization. Kink bands are notably absent from the immediate mine area but elsewhere show the typical northerly orientation and dextral sense. Major joint sets are subparallel to the main fault trends (Fletcher, 1969).

Description of vein

The Z-shaped bend of the Mountain Mine Vein at surface (Fig. 10) is typical of the main producing mines of the Allihies area (O Brien, 1948). The vein profile in depth is shown by the isometric drawing in Figure 11. The East-West Vein strikes at 67° and dips north at 82°. At the junction with the North-South Vein, the "Horse of Killas" splits the vein into North and South branches, this wedge of bleached wallrock being up to 21m wide and at least 60m long. The vein is 18m wide on surface east of the Horse of Killas, but thins to about 3m near the Cornish Village Fault, across which the structure continues for over 330m.

The North-South Vein strikes at 337°-355°, dips at 64°-67° NE and is 66m long near surface. A slight steepening in depth gives some extension downwards. At the north end two "horses" of brecciated chloritic wallrock each about 135m deep, and up to 18m wide split the vein into variable hangingwall and footwall branches. Below this the vein width is fairly constant at about 10m (Matthews, 1964).

The West Extension Vein is only intermittently seen on surface, but swells to a 7-12m wide lens 450m below ground level. The dip is about 68°north but the strike swings from 255° to 280° as the vein approaches the "45° Fault". Although the structure does appear to continue further west, no continuation of the Vein has been proved.

The New East-West Vein extends for some 195m west (290°) of the North-South Vein before it horsetails out into early joints, although the fault may continue westwards (Fletcher, 1969).

There is some uncertainty as to whether the Dooneen-Mountain Mine Fault joins the Mine structure along the New East-West Vein (Matthews, 1964), along the West Extension Vein and the south branch of the East-West Vein (Sheridan, 1964), or along the north branch of the East-West Vein (Fletcher, 1969).

Mineralization

The bulk of the vein is made up of opaque massive coarse-grained strained quartz, the opacity being due to the content of fluid inclusions. Vugs up to 15cm across are lined with cystals up to 13mm long. A breccia of unaltered angular rock fragments may occur but rock fragments are usually ingested, resulting in a mottled green or buff quartz containing disseminated chlorite and sparse carbonate. These varieties may alternate in ribbon structure. This largely barren early quartz has been partially recrystallized to fine-grained unstrained transparent quartz associated with copper sulphides and up to 25% albite and 20% carbonate. when containing disseminated molybdenite, this quartz has a grey "cherty" appearance (Fletcher, 1969).

Three well-developed ore shoots occur in the East-West Vein extending into the West Extension Vein. These pitch at 37°-47°E and range from 60-150m in length, 2-3m in width and 120-165m in depth. There is some evidence to suggest that the Ore Shoot Fault may control their lateral extent. The stronger mineralization is associated with molybdenum-bearing quartz (Fig. 12). The mineralization in the North-South Vein is weaker and irregular and is concentrated near the hangingwalls and footwalls of higher levels. Ore shoots in the New East-West Vein occur in a series of lenses 1-18m in length and at best up to 1m in width near the intersection with the North-South Vein. Chalcopyrite is the dominant mineral with tetrahedrite and pyrite significant in the East and West Extension ore shoots (Matthews, 1964).

Wallrock alteration

Adjacent to the vein and in vein inclusions the wallrock is intermittently altered to a buff to pale grey colour with reduced grain size and a high proportion of disseminated ferroan dolomite and numerous quartz-carbonate-copper veinlets. Outside this sericitic zone is a propylitic zone where first light, and then dark, green colouration reflects the chlorite content, both disseminated and on fracture or cleavage planes. The full zonation is not always present, and alteration may vary from a selvage up to 10m wide near major veins. The zones may be repeated by shearing or offset by late faults.

Surficial oxidation

The apparently barren nature of the outer metre or so of this quartz vein at outcrop has been commented on. The presence of gossan on the footwall of the East-West vein was noted by Smyth (in Kinahan and O'Kelly, 1860). Malachite, azurite and ferromolybdate are common in old stopes, and botryoidal goethite also occurs in vugs.

Mount Gabriel West Mine

Exploration and development

The mountain ridge north of Schull was a focus of copper mining activity in Bronze Age times (1270±90BC) (Jackson, 1968). There was renewed activity about 1860 at Letter copper mine (Fig. 13). Six small-scale barite-quartz veins were prospected or mined at about this time and later during the First World War, but only some 6,000t of barite was raised. Mount Gabriel West Mine will be described to illustrate some of the features of this group of veins.

Regional stream geochemistry (Lett, 1969) contributed to a renewed interest in the area, and a detailed soil geochemistry and IP programme by Minerex Ltd. for Acme Oil and Gas led to the drilling of 5 boreholes in 1972. Four of these (739/2 to 739/5) were drilled on nearly coincident copper and IP anomalies along the westward extension of the Skeagh Barytes Vein Fault. Two intersections on the fault zone gave 13.5m of 0.5% Cu with associated barite veining and up to 30 g/t Ag (Kiernan, 1972).

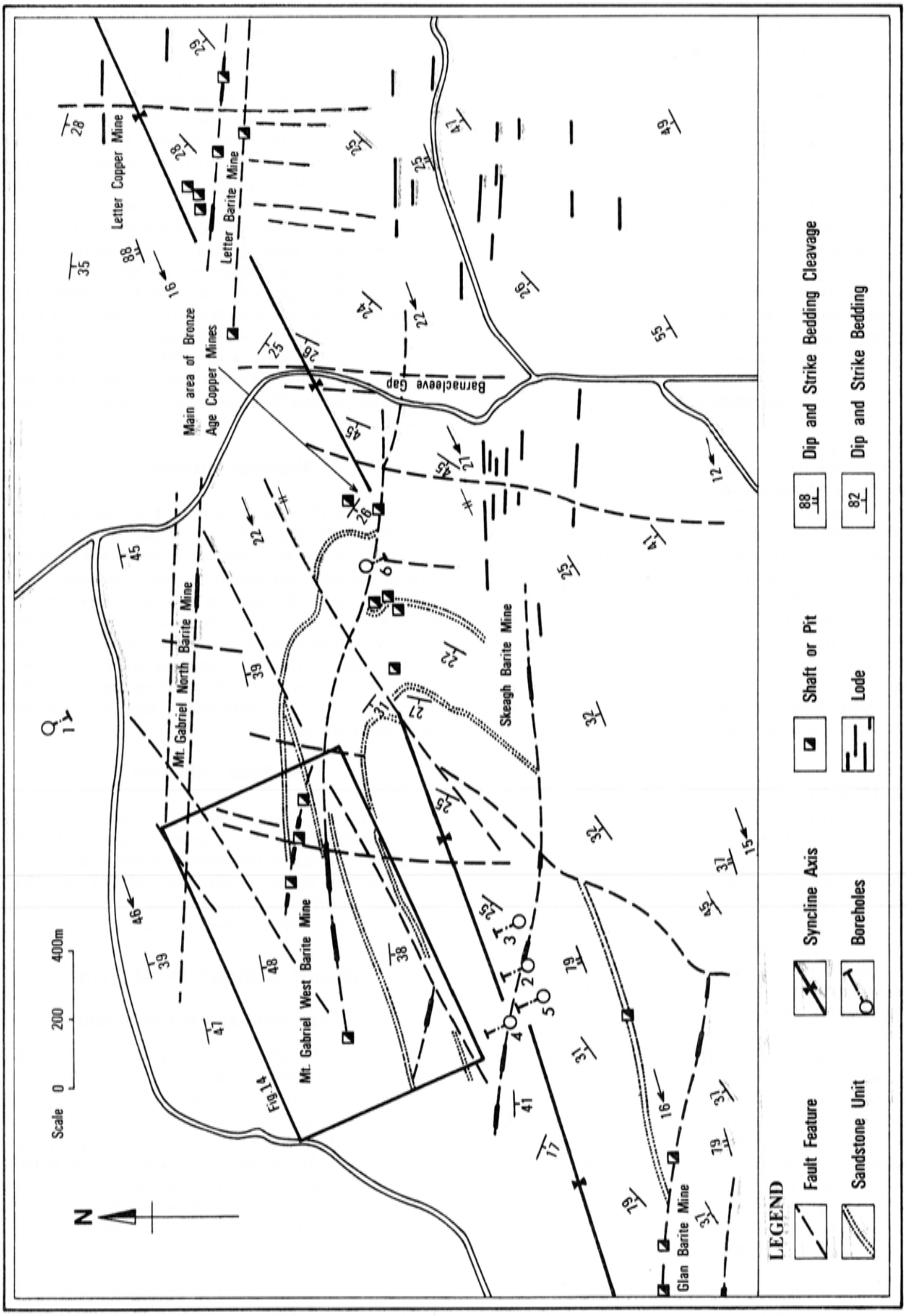

Figure 13 Veins in the Mount Gabriel area and location of drilling by Acme Oil and Gas.

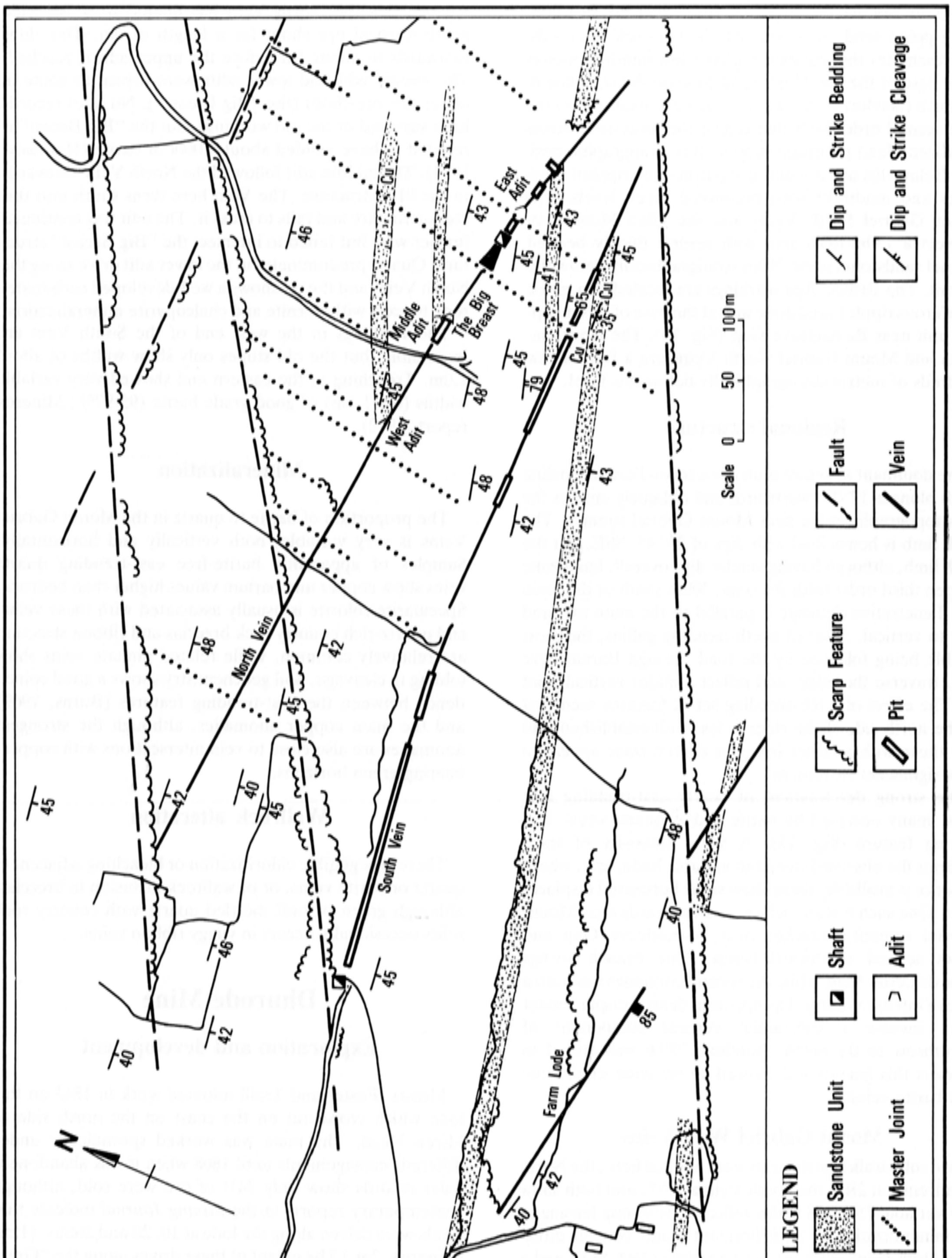

Figure 14 Sketch map of Mount Gabriel West barite mine.

Regional stratigraphy

In the uppermost 150m of sediment on the Mount Gabriel summit, two 4-6m thick grey, thickly bedded, channel sandstones are overlain by green, thinly bedded, fine-grained, rippled sandstones with purple mudrock interbeds. This resembles the sequence within a few hundred metres of the base of the Toe Head Sandstone on the coastline to the north (Naylor, 1975) and thickness estimates across the three second order folds that repeat the succession across the Mizen Head peninsula support this stratigraphic position. Below this unit are uniform purple-grey rippled sandstones and mudrocks with occasional green levels. The Mount Gabriel South Veins and the Glan Mine Vein intersect a 130m thick unit with several thickly bedded channel sandstones some 200m stratigraphically below the summit. The Bronze Age workings are located in a green cupriferous rippled sandstone unit at the base of this mappable unit near Barnacleeve Gap (Fig. 13). The Knocknageeha and Mount Gabriel North Veins are a further few hundreds of metres stratigraphically below this level.

Regional structure

The dominant structure is an open second order syncline which plunges 12°-25° westwards and obliquely crosses the main topographic ridge near Mount Gabriel summit. The north limb is homoclinal with dips of 25°-45° SSE, but the south limb, although having similar dips overall, has a zone of open third order folds for some 300m south of the main axis. Penetrative cleavage is parallel to the main axis and near to vertical. A set of north-trending gullies, the most notable being followed by the road through Barnacleeve Gap, traverse the ridge, and reflect a major vertical joint set. The effect of a NE-trending set of features seen best on the north side of the ridge is less well established, but only those with a rather irregular curved trace appear to show significant movement.

The strong development of nearly east-trending features, many occupied by barite and/or quartz veins, is a striking feature (Fig. 13). A slight sinuosity of trace confirms the observed steep but variable hade, and, where evidence is available, these show some horizontal displacement. One such feature, which runs eastwards near Mount Gabriel summit, branches near Barnacleeve Gap and shows several southward bends. One branch swings towards Letter Mine while the second continues east into a zone of intense veining. The apparent dextral displacement could involve a substantial vertical component of downthrow to the north. Borehole 739/6 was drilled to intersect this feature and showed an 8m wide shear zone with barite veining.

Mount Gabriel West Veins

Two subparallel barite veins were worked here; the North Vein trends at 280°, the South Vein at 270°, and both show very variable 75°-88° S hades reflected by strong lensing of the mineralization in both horizontal and vertical directions. Both veins cross-cut local bedding (260°/45°S) and a penetrative cleavage (250°/80°S). The South Vein has a strike length of 600m over a vertical range of 180m while the North Vein, although of similar length, is mineralized for only 250m at its eastern end. The veins strike towards the major feature which runs east of Mount Gabriel described above, but continuity has not been proved. The sandstone unit (Fig. 14), which is cut by both lodes, shows 60m sinistral shift on the South Vein and 240m on the North. In the latter case shear planes in the barite suggest a predominant horizontal component.

The main workings were situated at 225m OD where a strong vertical scarp marks a major cross feature at 014°. Against this the North Vein has dilated to a 7m wide nearly-vertical ore shoot for a length of 9m. This thins eastwards to about 1m before the upper adit is reached. The middle adit and lower adits were driven to come in under this ore-shoot (the "Big Breast"). No sales records have survived of the old workings, but the "Big Breast" is reputed to have yielded about 3,000t of barite (Hallissey, 1923). The middle adit followed the North Vein eastwards to the 014° structure. The Vein here turns south into this cross-structure and fails to cross it. The adit was continued further west but failed to intersect the "Big Breast" structure. Quartz predominates in the lower adit drive along the North Vein, and the tip shows a well-developed carbonate-rock breccia with bornite and chalcopyrite mineralization.

The workings in the west end of the South Vein are inacessible, but the old stopes only show widths of about 1.0m. Trenching at the eastern end showed very variable widths (0.1-1.1m) of good grade barite (95-97%; Minerex report, 1972).

Mineralization

The proportion of barite to quartz in the Mount Gabriel Veins is very variable, both vertically and horizontally. Samples of apparently barite-free east-trending quartz veins show copper and barium values higher than bedrock. Specularite/chlorite is usually associated with these veins, and quartz-rich country rock breccias and ribbon structure are relatively common, while related pinnate veins show folding in cleavage. Soil geochemistry shows a good coincidence between the east-trending features (Burns, 1969) and the main copper anomalies, although the strongest anomalies are also close to vein intersections with copper-bearing green horizons.

Wallrock alteration

There is negligible chloritization or bleaching adjacent to quartz or barite veins, or of wallrock inclusion in breccias, although green or buff mottled quartz with country rock relics occasionally occurs in vuggy ribbon veins.

Dhurode Mine

Exploration and development

Messrs. Foster and Traill initiated work in 1843 on this lode which crops out on the coast on the north side of Mizen Head. The mine was worked sporadically under different managements until 1868 when it was abandoned. Sales records show only 341t of ore were sold, although contemporary reports in the *Mining Journal* indicate that levels were driven along the lode at 10, 20 and 26fms. (1fm. is approx. 2m.) The extent of these drives along the "Great Counter Lode" is uncertain, but it was possibly in excess of 150fms, and there also may have been a short drive at 30fms. depth.

Stratigraphic setting

The Dhurode Fault brings the west end of the vein to within 50m of the top of the Toe Head Formation on the

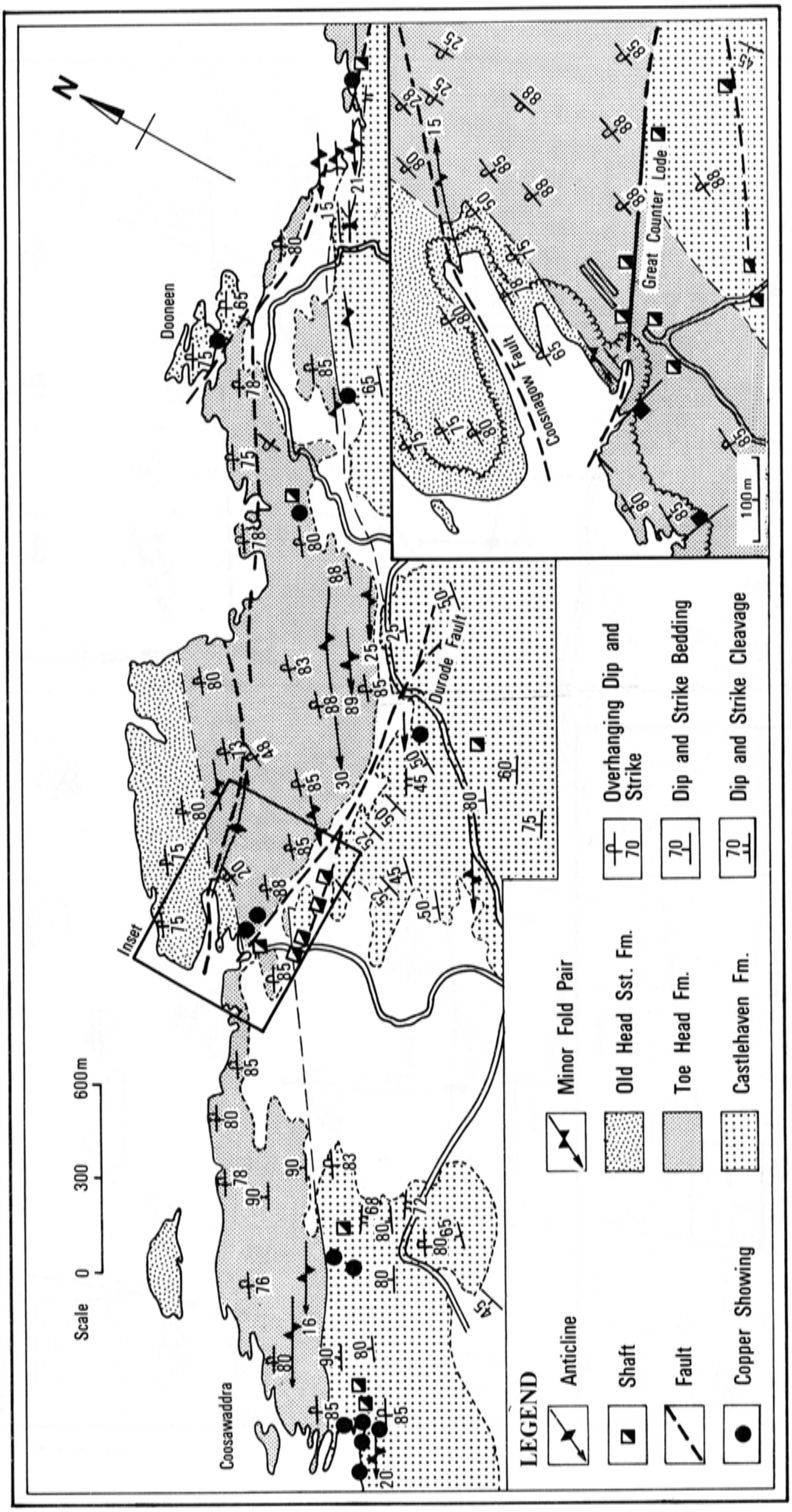

Figure 15 Sketch map showing the geological setting of Dhurode Mine.

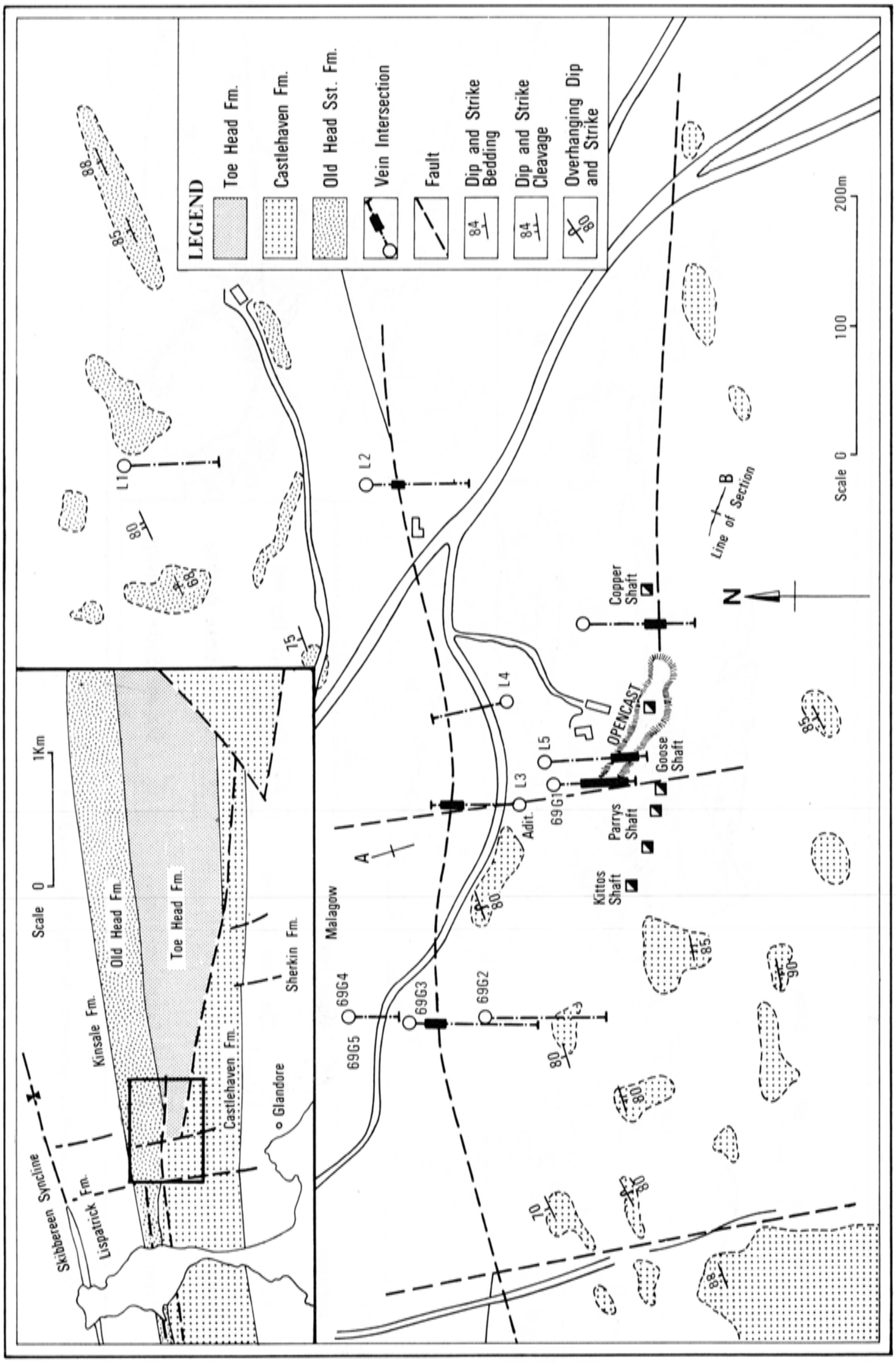

Figure 16 Sketch map of Glandore Mine area showing borehole locations by Argosy Mining Corp., and Irish Metal Mining Ltd.

north side while to the south the base of the formation is 70m east of the Engine Shaft (Fig. 15). "Copper bed" mineralization is well developed on the coastal section at Balteen, 3.2km to the east, and sporadic copper showings have been found inland.

Structural setting

The "Great Counter Lode" is developed in a steep sinuous ESE-trending fault which runs oblique to the almost vertical homoclinal north limb of the Ballydehob Anticline (Kinahan, 1861). This fault displaces the basal contact of the Toe Head Formation some 550m dextrally, before turning into strike at its eastern end. The fault crosscuts in plan view the nearly vertical bedding and cleavage at 40° to strike along its length. Some 200m west of the vein outcrop in Coosnagow, the Dhurode Fault must intersect a SSW-trending fault which follows a major topographic feature eastwards to Dooneen Coos (Fig. 15). Here it appears to intersect another east-trending structure causing slight dextral offset. The Coosnagow Fault hades 74° N and a downward facing anticline which is developed along much of its length plunges at 20° to the east. This plunge is opposite to the 20°-25°WSW seen along the Dhurode structure. A master NW-trending joint set, which is nearly vertical, is the other notable structure in the mine area.

Description of vein

The vein is exposed only in the sea cliff where it is 2m in width, with a clayey fault gouge on both walls. It contains three lenses of country rock. There is a suggestion in contemporary records that the vein was split inland. Three opencast workings are located immediately to the north.

Vein mineralization

The exposed vein contains chalcopyrite with patches and veins of calcite and dolomite. In dump material, arsenopyrite with rare galena and bornite have been identified (Snodin, 1972). The sandstones in the opencast workings contain sparse disseminated chalcopyrite and arsenopyrite. Reports of gold (Kinahan, 1861 and Cole, 1922) appear to have arisen from assays reported in the *Mining Journal* of 1843 and 1844 of 1.1 oz/ton from quartz, 0.1oz/ton from gossan. In view of the financial scandals involving the mine at this time these results must be viewed with scepticism. The presence of molybdenite has been noted by Fletcher (1969).

Wallrock alteration

There appears to be some silicification adjacent to the main vein together with bleaching of included wallrock lenses, but there is little obvious chloritization of wallrock.

Surficial oxidation

A very well-developed gossan, together with green and black copper (malachite and tenorite?), is mentioned in contemporary mine reports.

Glandore Mine

Exploration and development

The high copper content of the peat in a small bog at Malagow, 3.2km south of Leap village, was known by 1810 (Townshend, 1810). This peat was burnt for cupriferous ash between 1812 and 1816, producing some 262t of 10-15% Cu ash. Townshend drew the implication of a nearby source for the copper, and trenching by Colonel H. Hall revealed Mn-Fe-Ba-quartz float, but it was not until 1840 that the Main Lode was discovered and opencast manganese mining initiated. About 1869 a copper lode was discovered and the "Copper Shaft" was sunk to adit level although only some 70t of ore appear to have been sold. Between 1850 and 1880 minimal development was carried out. In all a total of 17,800t of manganese and 1,000t of iron ore were raised. The area was considered for possible wartime production (Rundall, 1939). As a result of geochemical and geophysical exploration, Argosy Mining Corp. Ltd. drilled five boreholes (L_1-L_5) in 1965 (Keele, 1968 and Lett, 1969). One hole (L_3) intersected a 13.7m wide lode north of Main Lode which gave 23% Mn, 1.7% $BaSO_4$, and 0.75% Cu while another (L_2) had an 8.5m intersection under the old workings which gave 19% Mn and 0.46% Cu. Following further exploration Irish Metal Mining Co. drilled an additional 5 holes (69 G1 to 69 G5). The high degree of cavitation has meant that mineralized zones give poor recovery, and assay and sludge values are tentative (Grennan, 1969).

Stratigraphic setting

The full stratigraphic succession from the Sherkin Formation to the Lispatrick Formation is represented on the west side of Glandore Harbour (Fig. 16), although major strike faulting cuts out all but 50m of the Toe Head Formation. To the east, in the mine area, it appears that the Toe Head Formation could be cut out completely. Some 300m NW of the opencast an *LN* zone date confirms Old Head Sandstone sediments (K. Higgs, pers. comm.) while immediately south of the easterly trending fault, typical Castlehaven Formation lithologies occur. All stratigraphic boundaries strike across the harbour without any offset. Typical green "copper bed" sediments with chalcopyrite mineralization were intersected in 69 G2 and 69 G3.

Structural setting

The mine is located on the homoclinal, nearly vertical south limb of the Skibbereen Syncline (Jukes, 1862). In the mine area, plunges of 10°-23° to the west reflect that of the major structure. In the Rosscarbery Anticline to the south, the Sherkin Formation plunges at 6° to the east overall. The alignment of quartz lodes between Leap and Rosscarbery was first considered to indicate a "mineral channel", but Kinahan (1875) emphasized that these represented a fault lode. Mapping indicates about 2,000m dextral shift on this fault and the workings are sited in poorly exposed ground where the fault trend swings from easterly to become parallel to strike. The dominant joint direction is north to NNW with dips of 70°-85° eastwards. A strong topographic feature with this trend occurs 400m west of the mine, and a similar, but less well-developed, feature strikes towards the mine from the north. Folding is absent south of the main fault, but to the north several zones of tight asymmetric folds occur.

Description of vein

The Big Pit or Main Lode is still visible in the opencut where it strikes WNW. The Engine Shaft and Big Pit Shafts were sunk in the opencast, but only a sketch plan and cross

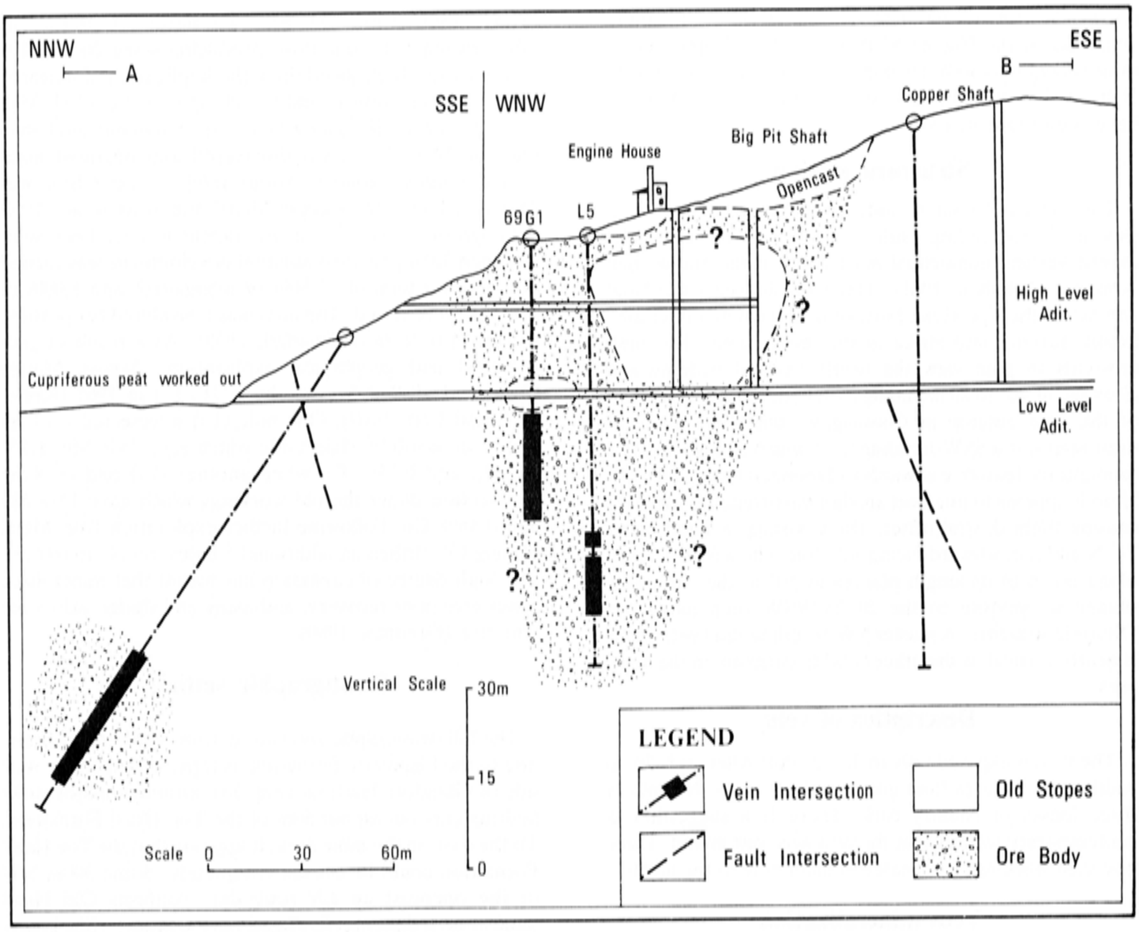

Figure 17 Longitudinal section of Glandore Mine after Rundall (1939).

section based on hearsay evidence (McCluskey, 1936 and Rundall, 1939) is available. This indicates that both shafts were sunk to adit level at about 36m below ground level, and that this level was later extended to the Copper Shaft (Fig. 17). The Main Lode appears to have been about 5m wide at maximum and about 43m long. A second lens 18m long and 3.6m wide (Rundall, 1939) known as Parrys Lode was subsequently found and stoped underhand for 3m below Lower Adit Level. This lens dipped steeply south as did the Main Lode. Both lenses run obliquely to the trend of the main fault which is inferred to run through 69 G3 and L_3 where it is marked in both by a very cavitated quartz-Fe-Mn breccia which may extend towards L_5. The Big Pit and Parrys lenses may be developed in antithetic shear zone utilizing a crossfault line. Purple and green Castlehaven sediments west of this zone do not accord with what appears to be badly disrupted Toe Head sandstones to the east (Fig. 17).

Vein mineralization

Kinahan (1884) described the ore as an angular quartz fault breccia cemented by haematite and later manganese, which might be the capping of a quartz-copper lode. Stalactitic and botryoidal forms were noted in early descriptions (Kinahan, 1861). There is some evidence for the falling-off in manganese content of the ore in depth. The earliest analysis quoted (Apjohn, 1884) indicated 82%Mn with 5.3%$BaSO_4$ and 1.3%Cu. Between 1881 and 1909 the fall in ore price suggests diminishing Mn content, while grab-samples from the waste tips near Big Pit ran at 46% Mn and 7% Fe (Rundall, 1939). Intersections in L_3 and L_5 gave only 18-24%Mn.

Lady's Well Mine

Exploration and development

The existence of barite at this locality was noted by Croker (1822) and Weaver (1838). With growing market interest the landlord, H. B. Beamish, began opencast mining about 1852 (Triphook, 1855). Intermittent production was continued from underground workings on the North Vein up to 1922 (Allen, 1918 and Cookson Company, report, 1922). In 1962 an attempt to dewater was hindered by shaft rehabilitation problems and successful re-entry by Milchem Inc. into the old 300 and 360 Levels for reserve assessment drilling was not achieved until 1976. This followed a surface drilling programme of 12 holes (DDH1-12). A final phase of surface drilling to evaluate the eastern end of the Vein followed initiation of production in 1979. The mine was worked until 1985 by NYM Ltd.

Stratigraphic setting

The North Vein is developed in the topmost tidal and barrier beach sandstone unit of the Old Head Sandstone

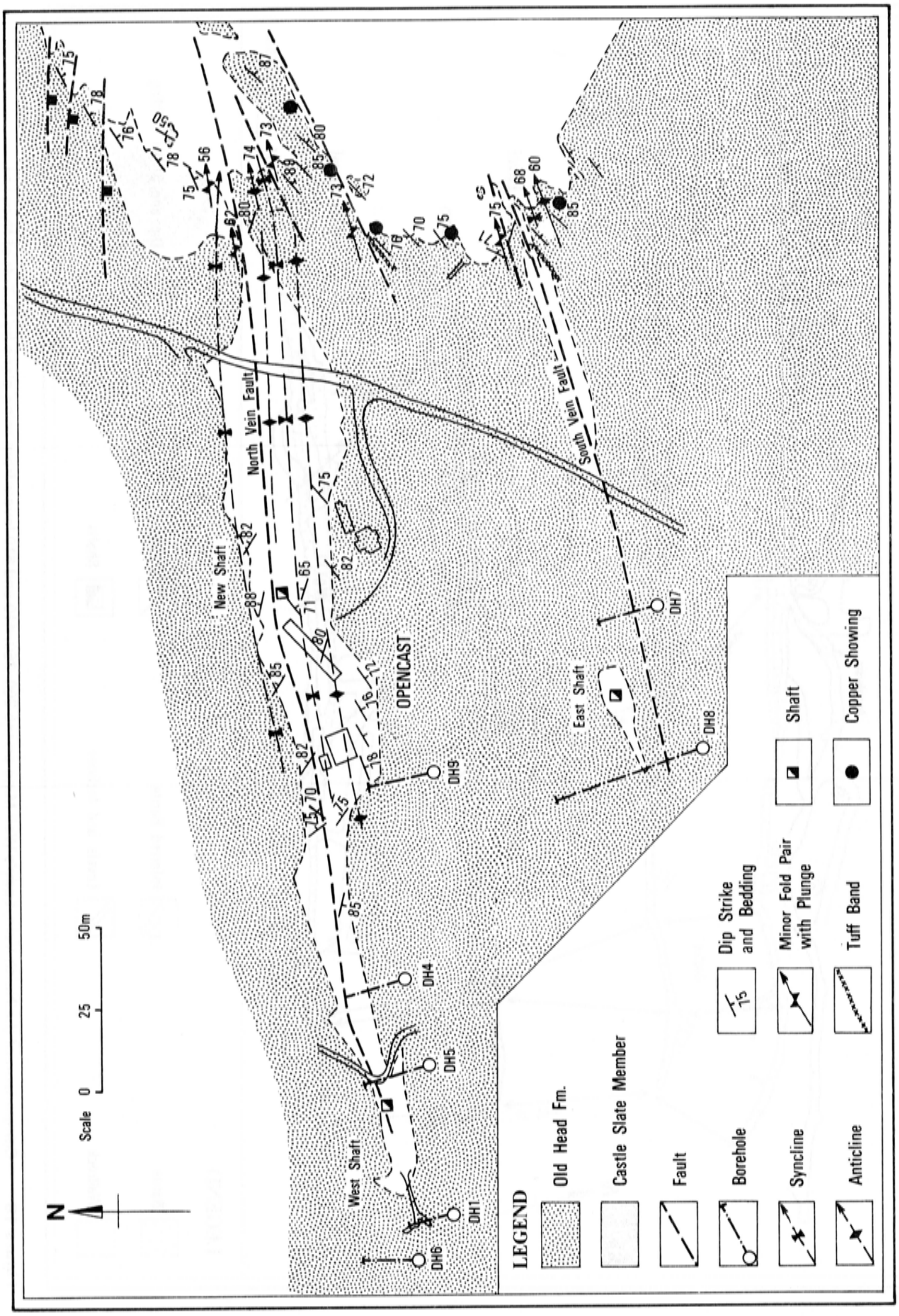

Figure 18 Map of Lady's Well Mine opencast with drill hole locations by Milchem Ltd.

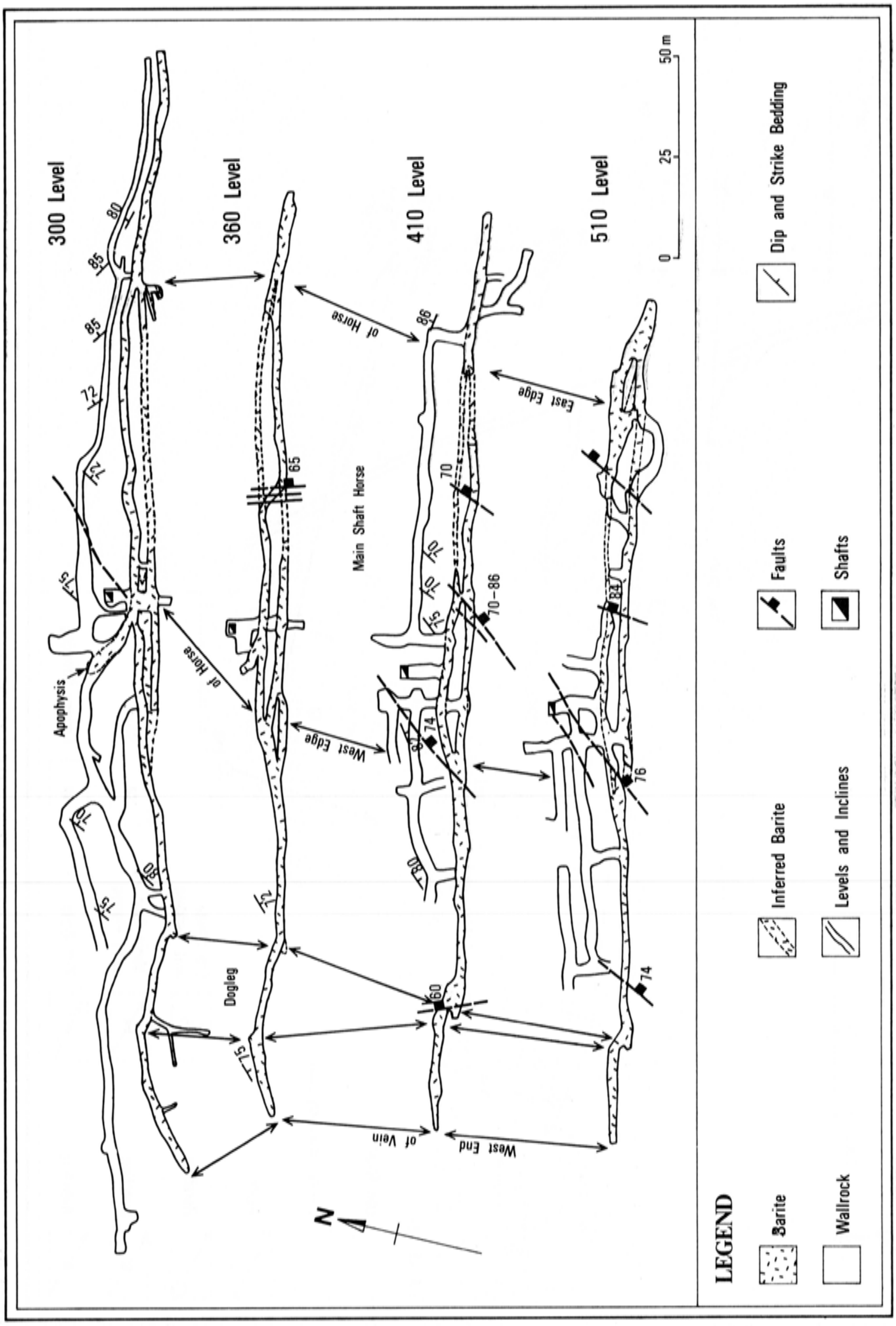

Figure 19 Comparison of the North Vein, Lady's Well Mine on the 300, 360, 410 and 510 levels from mine plans by D. Toft of Nym Ltd.

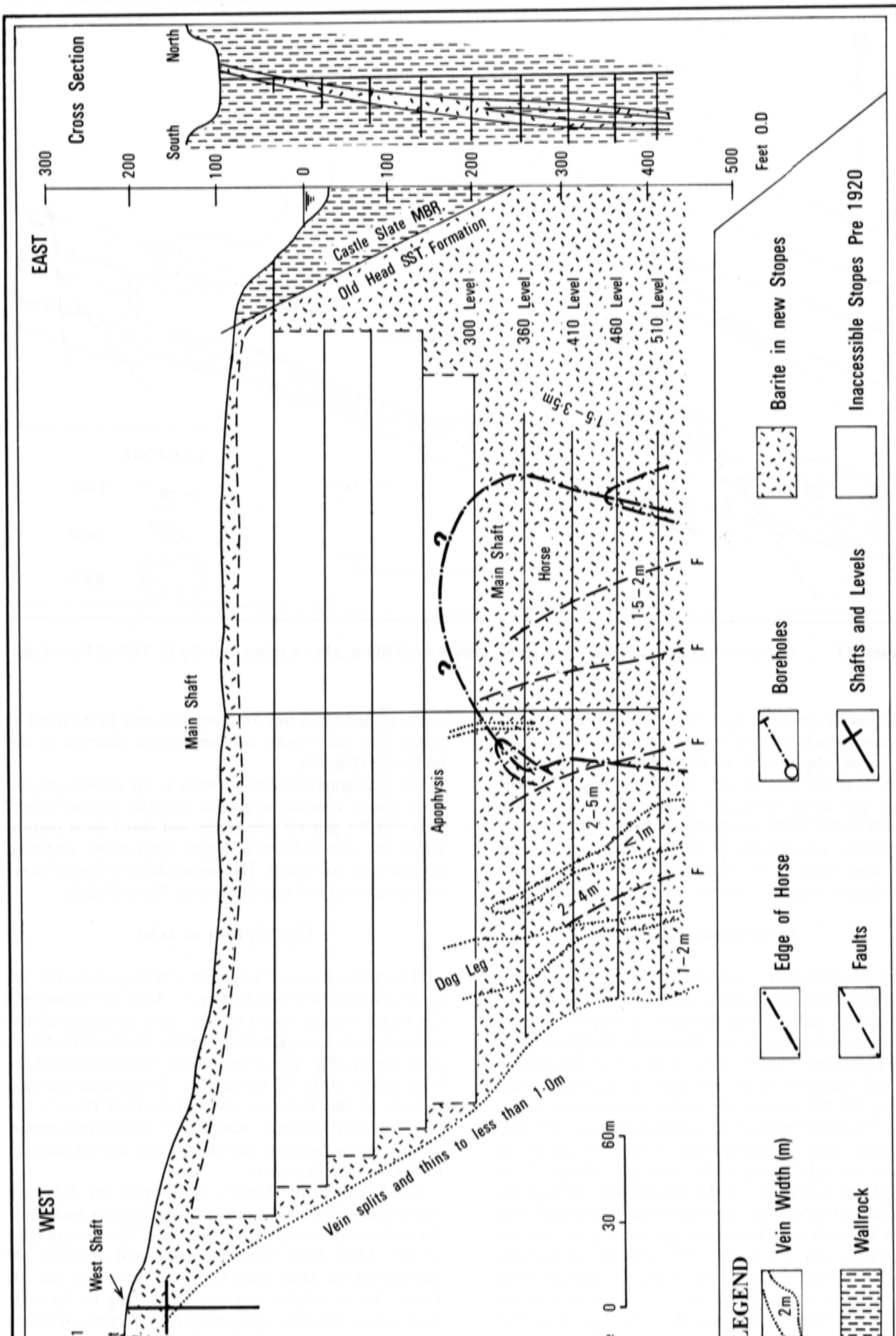

Figure 20 Longitudinal section of the North Vein, Lady's Well Mine based on sections by D. Toft of Nym Ltd.

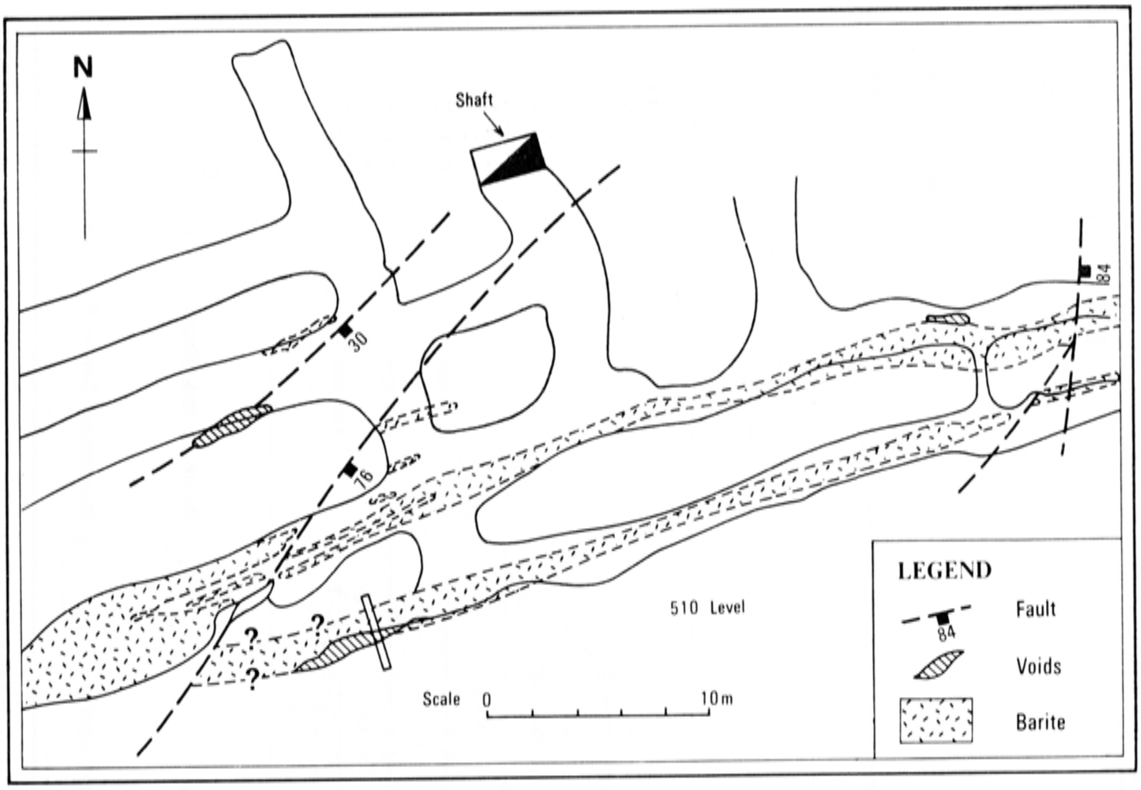

Figure 21 Cross faults near the shaft, 510 level, Lady's Well Mine, after a mine plan by D. Toft of Nym Ltd.

Formation of Strunian Age. The Castle Slate Member mudstone, which occurs in the footwall of the Vein at the coast, marks the base of the Carboniferous. A tuff band occurs near the base of the sandstones (Fig. 18). The greater part of the productive section of the Vein has a footwall in this sandstone-dominant facies. The hanging-wall contains a much higher proportion of mudrock thought to be from lower in the Old Head Formation, although palynological dating has not yet been carried out.

Structural setting

The Courtmacsherry Syncline traverses the headlands along the South Cork coastline. On Galley Head this Syncline is split by the Kilkerran Anticline, a complex structure which repeats the uppermost 180m of the Old Head Sandstone Formation along the 1km coastline between Duneen Bay and Muckross Head. At least 12 significant faults striking 250°-275° occur in this section (Graham and Reilly, 1978). The major structure has a regional plunge of 8° ESE calculated using the Castle Slate Member as datum. In contrast the tight folding in the mine area plunges 35° to 75° ESE and in this zone, on the opposite side of Clonakilty at Ballinglauna, Namurian sandstones and shales occur. The North Vein follows a fault which dips south at 81°, and has an irregular strike about 256°. On both sides of the Vein along the opencut the dip of the bedding is typically steep (75°-85°) with a few tight minor folds subparallel to the Vein. These folds are not thought to be related to fault movement. Fault drag has been observed on wave-polished surfaces to extend only a few centimetres into the South Vein footwall, and the folds do appear to be cut out along the strike of the Vein.

The Vein is thus typically at a significant angle (15°-45°) to the strike of wall rock bedding, but close to the trend of minor fold axial traces and penetrative cleavage in the mudrocks (Fig. 19).

The stratigraphic relation shown in the section and the steep plunge combine to give an apparent sinistral offset. However the general vein shape and riedel shear pattern within the vein indicate a dextral component, requiring reverse fault movement. Post-mineralization dextral shear on an early sinistral tear-fault seems less probable.

Description of vein

Plans and sections of the earlier workings above the 300 Level examined and reported on by Allen (1918) and in a Cookson Company report of 1923, have unfortunately not survived, and the longitudinal section, where derived from these reports (Fig. 20), is conjectural. Outline plans of the Vein on the 300 to 510 Levels (Fig. 20) illustrate the main features of the Vein, viz. the "Main Shaft Horse", the "Dogleg West", and the "Apophysis". Several post-mineralization cross-faults are also shown (Fig. 20) but have not been given specific names.

The "Main Shaft Horse", which splits the lode into North and South branches, is a lens of country rock some 3m wide at maximum and 75-96m long. The western edge of the "Main Shaft Horse" pitches west at about 45° intersecting the Main Shaft Cross-cut just below the 300 Level. An *en echelon* lens some 14m long by 2m wide occurs along this edge on the hanging wall of the 360 Level reducing the 7m vein width at this edge on the 300 Level. The eastern edge of the "Main Shaft Horse" pitches about 60° east and then turns to nearly vertical so that the Horse geometry is difficult to predict in depth. The split vein is variable in both width (1-3m) and quality. Some 6m west

Table 1.

Whole rock analyses of purple-grey mudrocks from Schull Bay (Snodin, 1972), the Cheverie Formation, Nova Scotia (Boyle, 1972) and the Allihies area (Reilly et al., 1980). Pb and Mo values include all rock types at Allihies, as separate calculation shows no difference. The Allihies results are taken from cumulative frequency curves.

Area	Element	Cu ppm	Pb ppm	Ba ppm	Mo ppm	Zn ppm	Ni ppm	Mn ppm	V ppm
Allihies	Mean	1	5	14	0.3	44	27	320	—
	Background	1.0-4.5	3-8	8-25	0.1-0.7	25-85	14-48	135-800	—
	N	93	216	86	233	94	94	94	—
Schull	Average	9 (7)	8 (5)	543 (340)	<1.0	57 (54)	N.D.	N.D.	188
	Range	1-23	2-13.0	440-755	<1.0	33-96	N.D.	N.D.	74-304
	N	14	14	14	14	14	—	—	14
Cheverie Nova Scotia	Mean	<5	6	694	<1.0	22	41	N.D.	N.D.
	Range	<5	<5-10	280-1600	<1.0-7.9	10-45	20-60	N.D.	N.D.
	N	10	10	10	10	10	10		

N.D.=No data. Figure in brackets after Schull average is mean value from curve for all 51 samples for comparison.

of the cross-cut on the 300 Level, a 1m vein turns NW into the footwall. This "Apophysis" was followed for 21m on the 300 Level.

The "Apophysis" intersection with the Main Vein is nearly vertical in the lower workings. In the opencast there is no clear evidence of such a structure.

In the Cookson Company report (1923) a fault was reported 60m west on the 360 Level and related to a necking of the Vein. On the 300 Level this section was inaccessible and was bypassed. The Vein branches about 80m west of the Main Shaft on both the 300 and 360 Levels. One branch turns westwards for 24-26m with Vein widths of 1-2m. The Main Vein extends only 5-20m beyond the join as evidenced by the failure of a drift south from the 300 Level to intersect it (Fig. 20). Beyond the west-trending section the Vein turns back to nearer the original strike for a length of 20-38m before becoming too narrow to work.

Any attempt to relate the Vein features described to those in the opencut, 120m above, must be highly speculative. The opencast extends from the Main Shaft 195m to the West Shaft and a further 18m to the West Adit. East of the shaft the opencut extends a further 160m to where the Vein, 0.8m thick, was exposed in the coastal cliffs. The lode in the West Shaft stops abruptly just beyond the Shaft (Fig. 19) and Allen (1918) links this with the splitting and thinning of the Vein reported in the west end of the old workings including the end of the 300 and 360 Levels. This suggests that mineralization pitches east at 45°-60° (Fig. 20). This pitch appears to steepen below the 360 Level and become closer to the nearly vertical pitch on the "Dogleg" and "Apophysis" structures at depth.

At 110m west of the Main Shaft in the opencut the Vein is exposed and about 1m thick, and for the 50m section beyond this there is a narrow section which has turned westwards off the main trend of the opencut. This could be the beginning of the "Dogleg" section at surface.

Vein mineralization

The barite resembles that at Derryginagh, except that there is less finely disseminated quartz, and pyrite is more common.

Wallrock alteration

The sandstones are extensively bleached, veined and iron-stained up to 25m away from the Main Vein. In this zone the barite veining post-dates early quartz gash veins. There is negligible alteration to mudrock units.

Regional setting of mineralization

Extent of the mineralization

The distribution of both known "copper bed" showings and of vein deposits is strongly concentrated near the southern coastline area (Figs. 1 and 3). This could be a reflection of prospecting activity, since the early prospectors tended to walk the coastline where malachite-stained beds and veins were most easily found. However, the geologists of the Geological Survey traversed the inland areas about this time without locating a similar density of mineralization (Fig. 1). The quality and cover of available reconnaissance stream geochemistry is uneven, but the distribution of anomalous copper is concentrated in the areas of known mineralization. A greater northwardly extent of above-threshold barium may be due to the effect of Devonian lavas and tuffaceous sediments which have barium values considerably higher than normal red-bed sediments (see Table 1). Thus very limited data have not provided any evidence for extending the Carbery district mineralization significantly northwards. Although vein deposits are known from all stratigraphic levels, they are most frequent near the base of the Toe Head Formation to the east and in the Allihies Sandstone to the west.

Intra-basinal volcanism

The base of the red-bed succession is nowhere exposed in the Carbery district, but limited miospore and fish data (Higgs and Russell, 1981) suggest that the observed red-bed sequence is Frasnian and Fammenian in age, and thins from some 6km to 2km southwards between Iveragh and the south coast. Deep basin margin faults may mark the northern margin of the basin (Naylor and Jones, 1967) and may have acted as a focus for Frasnian? volcanicity. The nearest established centres near Valentia and Lough Guitane (Penney, 1981 and Avison, 1982) are more than 26km from the Carbery district, although a Frasnian tuff (Fig. 2) has been found on Clear Island (Graham and Reilly, 1972).

Thin tuff bands are also found in many areas near the top of the Old Head Sandstone Formation (Fig. 2) but no intrabasinal volcanics of this age have been identified.

Stratiform mineralization

'Copper Bed' showings are frequent in the South Cork area (Fig. 3) where they are strongly concentrated in thin channel-sandstone units near the base of the Toe Head Formation. The number of known showings decreases down the succession even though concentration in similar sand bodies deeper within the Castlehaven Formation (Tower Member of Reilly and Graham, 1976) does occur in the southernmost part of the district. Very few showings occur in the Sherkin Formation sandstones.

A fall-off in the frequency of showings in the Allihies area (Fig. 3) is evident. Again the showings are concentrated near the base of the Toe Head Formation. The paucity of showings deeper in the redbed sequence on the Beara Peninsula may reflect the overall finer mid-basin facies and lower palaeo-water table. There is a slight overall change in red-bed colour which becomes paler on Iveragh and Beara.

Snodin (1971) proposed that interstitial brines expelled from the compacting marine basin to the south (Fig. 2) migrated through the uppermost Devonian red-beds. High volume flow was concentrated in thin coarse-grained channel units in red mudrock-dominant sequences where leached metals were precipitated by sulphide produced in anaerobic sub-watertable conditions by sulphate-reducing bacteria.

An alternative or additional source of metals might be deep basin compaction brines (Cathles and Smith, 1983) utilising the basin margin facies (Fig. 2) to migrate outwards and upwards.

There are some geological constraints to these models however. Marine conditions were established along the southern coastline only in late *LE* Zone times when the upper part of the red-bed sequence below the Toe Head Formation was being deposited further NW (Clayton and Higgs, 1978). Gardiner and Sheridan (1981) have concluded, from available data including two offshore wells (55/30-1 and 63/4-19), that during the Frasnian-Fammenian no marine incursion advanced north of an "Anglo-Welsh Platform" some 150km to the south. Thus, although laterally scavenging marine brines and a high water table might arguably be available to enrich selectively the Strunian "copper beds" and subsequently intersecting vein systems, these conditions did not apply earlier.

Structural setting

The individual veins described above have widely varying styles, and illustrate a wide range of angles to dip and strike of bedding and cleavage. Neither is competence of wallrock nor position with respect to major fold axes uniform. However, there is a characteristic association of barite, manganese and copper mineralization with nearly east-trending (usually dextral) faults, and NE and north cross-faulting. Probable control of mineralization by pre-existing structures has been demonstrated at Derryginagh, Mount Gabriel and Lady's Well, and this is also a notable feature at Allihies (Sheridan, 1964). A close relation between mineralized E-trending faults and strike faults has been illustrated at Crookhaven and Glandore. Both these fault/vein sets clearly post-date the main formation of regional axial planar cleavage, but they are considered to be late syntectonic on such evidence as general setting, folding of related veinlets in cleavage, and offsets by bedding-plane slip. Throughout the area and northwards in the Munster Basin, non-mineralized nearly east-trending faults are frequently described (e.g. Capewell, 1957 and Dolan 1984). A cursory examination of airphotos in well-exposed areas does not indicate that this structural element is either more or less well-developed in the Carbery district than to the north, although there is some suggestion that known vein mineralization is associated with increased photofracture density (Bailey, 1980).

The often tight asymmetric folds associated with strike faulting and less frequently with east-trending faults may locally diverge up to 10° from the first order axial trends and show oversteepened or reversed plunges. However, as only slight drag and minor crenulation of regional cleavage is developed, the two distinct fold phases described by Coe and Selwood (1963) and regarded as possibly pre-Namurian and post-Westphalian by Gill (1962), are not demonstrable, although a late-stage tightening of folds with fault rejuvenation is probable. Sulphides in veins show partial recrystallization textures (Snodin, 1971) as does the gangue, and similar textures are found in barite. Both presumably reflect this late-tectonic adjustment under dextral shear (Sanderson, 1984).

Intrusives

Minor intrusives ranging from dioritic to trachytic are frequent around the Beara and North Sheeps Head coastline (Boldy, 1955 and Viswanathia, 1959). These appear to represent onshore a more extensive area of intrusives shown by aeromagnetic data to extend offshore to the SW (Max et al., 1982). In drilling at Kealogue Mine a trachytic intrusion along the fault was considered to pre-date the quartz-copper lode (Matthews, 1964).

The fluidized breccia pipes of the Black Ball Head area and some 60 other smaller tuff dykes (Coe, 1966 and 1969) contain ultrabasic xenoliths which sets them apart from the intrusive breccias and related quartz porphyry dykes found within 1-2km of the Cornubian granites (Goode and Taylor, 1980). The occurrence and alignment of these bodies is suggestive of the presence of deep-seated fractures (Coe, 1966 and 1969; Matthews et al., 1983). Several phases of intrusion may be present occurring before and during the main phase of folding (Coe, 1966). Tentative palaeomagnetic data also support a late Carboniferous to early Permian age (Morris, 1970) for some intrusives.

The −10mGal anomaly centred about Killarney has been modelled to fit a granite body at about 8km (Howard, 1975) and the occurrence of similar anomalies northeastwards towards the Leinster Granite carries implications of a similar Caledonian age (see Browne and Brock, 1983, for a review of data sources). The flooring of a rapidly subsiding Devonian basin with granite seems unlikely and Naylor and Jones (1967) preferred to postulate an increased thickness of sediments. The presence of a late orogenic Variscan granite can not be excluded (Matthews, 1964) but since the main areas of mineralization lie south of the +10mGal line on a steadily rising Lower Palaeozoic floor with concomitant thinning of the overlying sediments (Thirlaway, 1951), any connection of a granite with the mineralization seems unlikely, despite the presence of molybdenum (Sides, 1977) and rare tin values up to 0.5% Sn (Evans, 1976).

Radiometric data

K-Ar ages on clay concentrates suggest that the mineralization at about 290Ma post-dates by some 20-30Ma the

Table 2.

Cobbed copper ore samples from the Allihies and Mizen Head areas (Butler, 1963). The samples range from 1% to 35%Cu and 2% to 20% Fe. Many of the samples were monomineralic giving erratic results and the gangue is not properly represented. Samples with Pb in excess of 1% omitted. Manganese ranges up to 0.5%+ in Mizen Head samples, but is rare in Allihies area. Zn occurs at 1% + in both areas. N.D.=No data. Elemental concentrations in ppm. Non-detectable values taken as zero for average.

	Element	V	Cr	Co	Ni	Mo	Ag	Sn	Pb	Bi	Au
Allihies Area	Range	30-100	0-15	0-1000	0-75	0-350	0-700	0-150	0-1500	0-1500	0
	Average	48	1	16	13	50	214	18	263	253	—
(13 samples)	Detectable	11	1	7	5	10	11	2	9	5	0
Mizen Head Area	Range	30-250	0-100	0-400	0-75	0-4000	0-1700	0-150	0-1200	0-2600	0-150
	Average	131	24	72	21	302	399	10	288	324	—
(17 samples)	Detectable	17	11	14	13	11	16	2	14	13	3
Lower Limit of Detection	(p.p.m.)	25	5	10	2	20	5	15	20	200	15

main deformation overprint (Halliday and Mitchell, 1982). Model lead ages for Cahermore (270±40Ma) and Killaveenoge (250±40Ma) only coincide within very wide error limits (Pockley, 1961). Both barite and copper veins give similar ages and this concurs with the similarity of the recrystallization textures described above.

The strong Permian secondary component shown by both red-beds and Palaeozoic volcanics (Howard, 1978) and the occurrence of some K-Ar ages extending into the early Permian (~270Ma) (Halliday and Mitchell, 1983) would appear to mark the completion of Variscan deformation. A Triassic age (208-230Ma) for the Glandore deposit is clearly anomalous, and may reflect a Mesozoic hydrothermal event at about 220Ma (Halliday and Mitchell, 1983). There is no other evidence for such an event elsewhere within the Munster Basin, although Permo-Triassic tectonic breccias may occur in Welsh wrench faults (Hancock et al., 1983). The Cloyne silica deposit near Cork City contains quartz veining which could suggest a hydrothermal origin (Bishop and McCluskey, 1948). Mid-Jurassic miospores found in the related "colbond" residual clay pockets (K. Higgs, pers. comm.) suggest but do not prove very early initiation of karstification which eventually led to the formation of chalk-filled collapse features such as those north of Killarney (Walsh, 1966). Associated angular breccias of quartz/chert in limonite/haematite matrix (Walsh, 1965) may relate to early Palaeocene weathering and silicification and appear dissimilar to the Glandore breccia. The Tertiary dykes in the area (Fig. 2) are now dated as 50-60Ma (Thompson, 1984) placing them in the main phase of Palaeocene igneous activity. There is no apparent relation to mineralization, although there is accumulating evidence of possible Tertiary movement (Mitchell, 1980).

Lithogeochemistry

Only limited data are available on the lithogeochemistry of the Munster Basin sediments and veins, and further work is necessary. Snodin (1972) gives results for 51 samples taken over 910m across the Toe Head — Castlehaven Formation boundary on the east side of Schull Harbour. Reilly et al. (1980) give data for 233 samples from the Allihies area, largely from proximal and distal red-bed facies lower in the Munster Basin succession. Results for purple mud and siltrock of these two areas are compared in Table 1 and show an increase in Cu and Ba towards the top of the succession with little difference in Pb and Mo. The difference is uncertain due to the limited number of samples at Schull and also to the problem of comparing possibly polymodal distributions. Comparison of the Schull results with those from the Tournaisian Cheverie Formation of Nova Scotia and the Permian red mudstones of SW England (Boyle, 1972 and Cosgrove, 1973) could support the possibility that there has been some leaching of Cu and Ba from the basin axis sediment. The volume of non-marine sediments in the Munster Basin has been put at 38,000km^3 (Graham, 1983). Taking the depleted zone as some 20,000 km^3 (see Fig. 2) there is more than ample Cu and Ba available to migrate into vein deposit sites to account for the estimated 300,000t of barite and 30,000t of copper already produced from vein deposits in the area, without invoking other sources (but see Evans, 1976, for discussion).

The gold values of several ounces per ton quoted in the reports of the last century must be regarded as probably promotional, as these were not confirmed by Lyburn (1901) who obtained at best only a few dwts in ore from Bantry, Rooska, Allihies and Bearhaven South mines and by Butler (1963) who found less than 15ppm in 28 of 30 cobbed ore samples from the district. However the presence of gold in modest values is confirmed by a best value of 0.57 oz/ton Au in selected float samples found near Durrus, although the average value was only 0.06 oz/ton Au (Thompson, 1963).

Summary

Syn- to post-tectonic intrusives and tuffisites and Fammenian volcanics may hint at enhanced heat flow and basement fault control within the Munster Basin (Matthews et al., 1983). The lack of a good spatial relation of vein mineralization to known outcrops of intrusives (Fig. 2) is only partially discounted by the more extensive volcanic area suggested by aeromagnetic data (Max et al., 1982). Spore exines are black (Fettes et al., 1985) representing a temperature range of approximately 230°-300°C (Staplin, 1977) for the pre-Mesozoic.

The sketchy evidence on vein geochemisty does suggest that there may be differences between the Allihies and South Cork areas (Table 2). In addition the latter veins, although showing similar structures, are also smaller, show less wallrock alteration and often show a close association of Ba with Cu. They are of course developed at a higher level in the stratigraphy where the bedrock tenor of Cu and Ba is enhanced, although the available evidence suggests that lateral mobility of stratiform mineralization into veins is limited (Snodin, 1972). The change in competence at these higher levels may be more significant, acting as a focus for stress and providing more frequent contrast of lithology across offsets. By comparison, such facies differentiation is much less well-developed on the Beara Peninsula, and might have led to differences in timing and volume of intergranuluar and fissure flow in the two areas in a model such as that proposed by Cathles and Smith (1983).

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