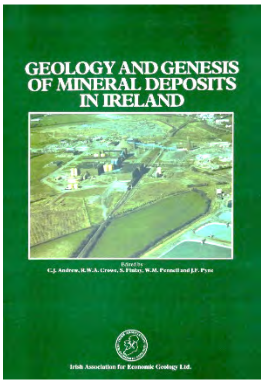

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The stratigraphic and structural setting of Zn-Ba-Pb mineralization at Newtown Cashel, Co. Longford.

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Abstract

The Newtown Cashel prospect is situated at the western end of the Keel Inlier. It consists of fracture-controlled zinc, barite and lead mineralization hosted predominantly by the Courceyan Mixed Micritic Unit but also extending down into the Basal Clastics Unit and up into the Upper Sandstone Unit. Drillhole results show that these Units are dolomitized in mineralized zones. Structurally the prospect is located at the western termination zone of the Keel Fault which bounds the southern margin of the Inlier. The Fault is believed to be a dextral shear zone which becomes listric and rotates clockwise in the prospect area. Mineralization is stratigraphically confined beneath an inferred unconformity that cuts out much of the upper part of the Courceyan limestone sequence but below which a previously unknown unit of pale grey Chadian micrite is preserved. Locally the micrite has mudbank or "reef" facies developed, and, where developed, the mudbank is brecciated and contains cavity-fill sphalerite and pyrite. Above the unconformity the limestones are completely replaced by vuggy white dolomite. This dolomite is thought to be hydrothermal in origin as it appears to be regionally related to areas of structural complexity such as the nose of the Inlier and major faults.

The mineralization is interpreted to be controlled by faults along the margin of the Inlier which moved during the early Carboniferous. It was emplaced prior to the unconformity, probably during the Chadian. Similarities in the structural and stratigraphic setting of the Newtown Cashel mineralization and orebodies such as Navan and Silvermines suggest that termination zones of syn-sedimentary transcurrent faults were preferential sites for Irish-style carbonate-hosted mineralization.

Introduction

Mineral exploration in the Newtown Cashel area commenced in 1972 when Amoco took up licences and conducted reconnaissance geochemical and geophysical surveys. Amoco's drilling was reportedly based on a coincidence of shallow-soil mercury anomalies and VLF-EM linears which corresponded to a change in the gravity gradient that was thought to mark the southern edge of the westward continuation of the Keel Inlier. The drilling confirmed this interpretation, and mineralization grading up to 6.3% Zn+Pb (over 1m) was discovered 2km NW of Newtown Cashel village on the downthrown side of the main fault. Mineralization was also found on the northern upthrown side of the fault. All the base metal sulphides are hosted in micrite and sandstone which comprise the lowermost units of the Courceyan sequence in the area.

In 1976 Amoco ceased active operations in Ireland, and the Newtown Cashel licences were farmed out to Noranda who operated the ground until 1979. Noranda carried out an extensive re-evaluation of the general area and conducted reconnaissance deep-overburden geochemical sampling, induced polarization and gravity surveys before continuing with diamond drilling. Several outlying targets on the Inlier were tested, but the bulk of their work concentrated on extending the known mineralization. Their results showed a continuation of the same style and grade of mineralization to the east and west of the original discovery, and as this was considered insufficiently encouraging, the licences were relinquished in 1979.

Aquitaine next worked the licences from 1981 until 1983 when they were farmed out to Chevron, the current operators. Work by Aquitaine consisted of a re-interpretation of the geology and the definition of a new target to the west of the previous drilling where mineralized, previously unsuspected, Chadian, "reef" mudbank limestone was discovered.

This paper concentrates on the stratigraphic and structural relationships of the mineralization at Newtown Cashel, and shows how these relationships are similar to some other mineralized areas in the Central Midlands of Ireland.

Regional geology

The regional geology of the Longford area is illustrated in Figure 1 which shows the location of the Newtown Cashel area at the southwestern end of the Keel Inlier.

The Keel Inlier is one of several NE-oriented, pre-Carboniferous inliers in the Central Midlands. Recent investigations confirm the hypothesis of Moore (1980) that these inliers are associated with dextral movement along major, NE-trending, transcurrent shear zones (Phillips and Sevastopulo, this vol.). However, the exact ages and positions of these faults are difficult to determine, and the mapped location of faults bounding the inliers (Fig. 1) are probably approximate. These structures are believed to be mainly post-Dinantian in age, although earlier periods of faulting were probably important in determining the shapes of the inliers.

At Newtown Cashel several unconformities provide evidence of this earlier phase of faulting. One is an interpreted disconformity (which cuts out the Upper Sandstone Unit) to the WNW of Corlea, and another is an unexposed unconformity (cutting out much of the Courceyan and Chadian) at Newtown Cashel. However, intense and widespread dolomitization around the end of the Inlier obscures these unconformities. The dolomitization appears both structurally and stratigraphically controlled, as it lies in close proximity to the known faults and is confined to the basal part of the post-Courceyan sequence.

Stratigraphy

A composite stratigraphic column for the prospect area (Fig. 2) is based mainly on unpublished reports by Philcox (1981), Haughton and Gurley (1982) and, for the pre-Chadian part of the stratigraphy, on a published report by Philcox (1984). In the absence of any formal system of stratigraphic nomenclature, the informal terminology used by Aquitaine has been adopted in this paper (see Fig. 2). Philcox (1984) presents the regional correlations of the units.

Pre-Chadian stratigraphy

The lowermost rock unit intersected in the area is mottled, purple and green greywacke of probable Ordovician age which is in fault contact with the overlying Mixed Micritic Unit (in hole L19; see Figs. 3 and 6). Regionally, however, the Lower Palaeozoic rocks are unconformably overlain by either Old Red Sandstone facies of Late Devonian to early Carboniferous age or the Basal Clastics Unit of the marine Courceyan sequence. Differentiation of these two clastic units was attempted by Amoco (core not available), but in this paper all the basal sandstones are assigned to the Basal Clastics Unit.

Lower parts of the Basal Clastics Unit contain discontinuous quartz-pebble conglomerates, but most of the units consist of indistinctly, medium- to thick-bedded, fine-grained, well-sorted, quartz arenite. Small and large-scale cross-bedding is common. Thick interbeds of black mudstone occur sporadically throughout the Unit and are particularly abundant towards the top of the Basal Clastics Unit where it is overlain gradationally, or with an interfingering contact, by the Mixed Micritic Unit.

The Mixed Micritic Unit, as its name implies, is a heterogeneous unit of shale, micrite and sandstone. The bedding is irregular, and individual members do not appear to be laterally continuous. Bioturbation is relatively uncommon, but small calcite-filled burrows occur in places (e.g. serpulid casts). In the study area, the Unit is characterized by a paucity of fauna compared to carbonate units higher in the succession. Small compactional structures, flaser bedding and small-scale, scour-and-fill structures are common. Dolomitization is variable and apparently increases towards mineralization (see below).

The Mixed Micritic Unit interfingers with the overlying Upper Sandstone Unit which, in the absence of an adequate vertical section, may be easily confused with the Basal Clastics Unit. Typically, it is less well bedded than the Basal Clastics Unit, has more micrite, shale interbeds and a calcareous matrix. The Upper Sandstone Unit is an important continuous marker in central Ireland (see Philcox, 1984), but at an outcrop 3km to the WNW of Corlea, the unit is absent and the Lower Limestone disconformably overlies the Mixed Micritic Unit.

Gradationally overlying the Upper Sandstone Unit is the Lower Limestone, a lateral equivalent of part of the Ballysteen Limestone in the south (see Philcox, 1984). The basal part of this unit is correlated with the Shaly Pales at Navan by Philcox, but this distinction is not very relevant at Newtown Cashel because most of the Lower Limestone is not present in the prospect area. The unit consists of medium to thick-bedded, argillaceous biosparite with laminated or thin interbeds of black mudstone.

The Waulsortian Mudbank or "reef" limestone (Lees, 1964) crops out to the east of the Newtown Cashel area at Corlea (dated by G. Ll. Jones, writ. comm., 1984), but no Waulsortian has so far been found in the prospect area. Like much of the underlying Lower Limestone, the Waulsortian and associated "off-reef" facies may have been deposited in the Newtown Cashel area and eroded prior to deposition of the post-Courceyan sequence.

Post-Courceyan stratigraphy

Overlying the Courceyan units is the unexposed Pale Micrite Unit of Chadian age (dated by Sevastopulo, writ. comm., 1982). In hole L21, the Unit consists of pale grey biomicrite and biopelmicrite, but to the west at Glebe, in hole GE 1 (see Fig. 3), most of this Unit (96m) consists of pale grey micrite typical of Irish Carboniferous "reef" or mudbank facies (Fig. 2). The Pale Micrite Unit is similar to the Waulsortian but generally contains fewer, distinct, mudbank textures, such as stromatactis and bryozoan mats, which may be due to poor preservation of such textures. Some of the Unit is sporadically bioclastic and brecciated, but 150m to the north, in an upfaulted block in drillhole GE2, the Unit has very few mudbank textures and consists of bedded biomicrite. This abrupt change could be explained either by lateral strike-slip faulting or extremely rapid facies changes. In either case, the Pale Micrite Unit clearly contains significant local facies variations.

Rocks overlying the Pale Micrite Unit consist of vuggy, white to pale orange dolomite in the prospect area (contact intersected in holes L21 and GE1, see sections B-B' and C-C' in Fig. 5). These rocks overlie the Pale Micrite Unit, the Lower Limestone, the Upper Sandstone and the Mixed Micritic Units by what is interpreted as an unconformity.

The dolomitization of the post-unconformity sequence is so intense that nearly all the pre-existing textures are destroyed. The Amoco logs indicate the presence of a basal breccia horizon, but in most of the currently available cores, this breccia only occurs as angular ghost fragments (up to 10cm in diameter) within the dolostone. In one hole (L21), gossanous haematitic material occurs immediately below the dolostone breccia, possibly suggesting sub-aerial exposure. However, the haematite could also have been precipitated from groundwater moving along the contact.

The nature of the unaltered rocks affected by intense dolomitization can only be gleaned from the Amoco logs which describe the unit as "pelloidal, crinoidal calcarenite-wackestone" with a middle chert unit which thickens and becomes progressively destroyed by dolomitization to the south towards L13 in Section 1 (Fig. 5).

The origin of this dolomitization is discussed below, but one feature worth noting is that the units underneath the inferred unconformity do not appear to have been affected by the intense dolomitization affecting those rocks above it.

Environment of deposition

The pre-Chadian Dinantian sequence was deposited as part of the general early Carboniferous transgression over central Ireland (Sevastopulo, 1981; Phillips and Sevastopulo, this vol.).

The Basal Clastics Unit is interpreted to be predominantly marine in origin, particularly near its top where it is known to contain fossiliferous horizons. Its well-sorted,

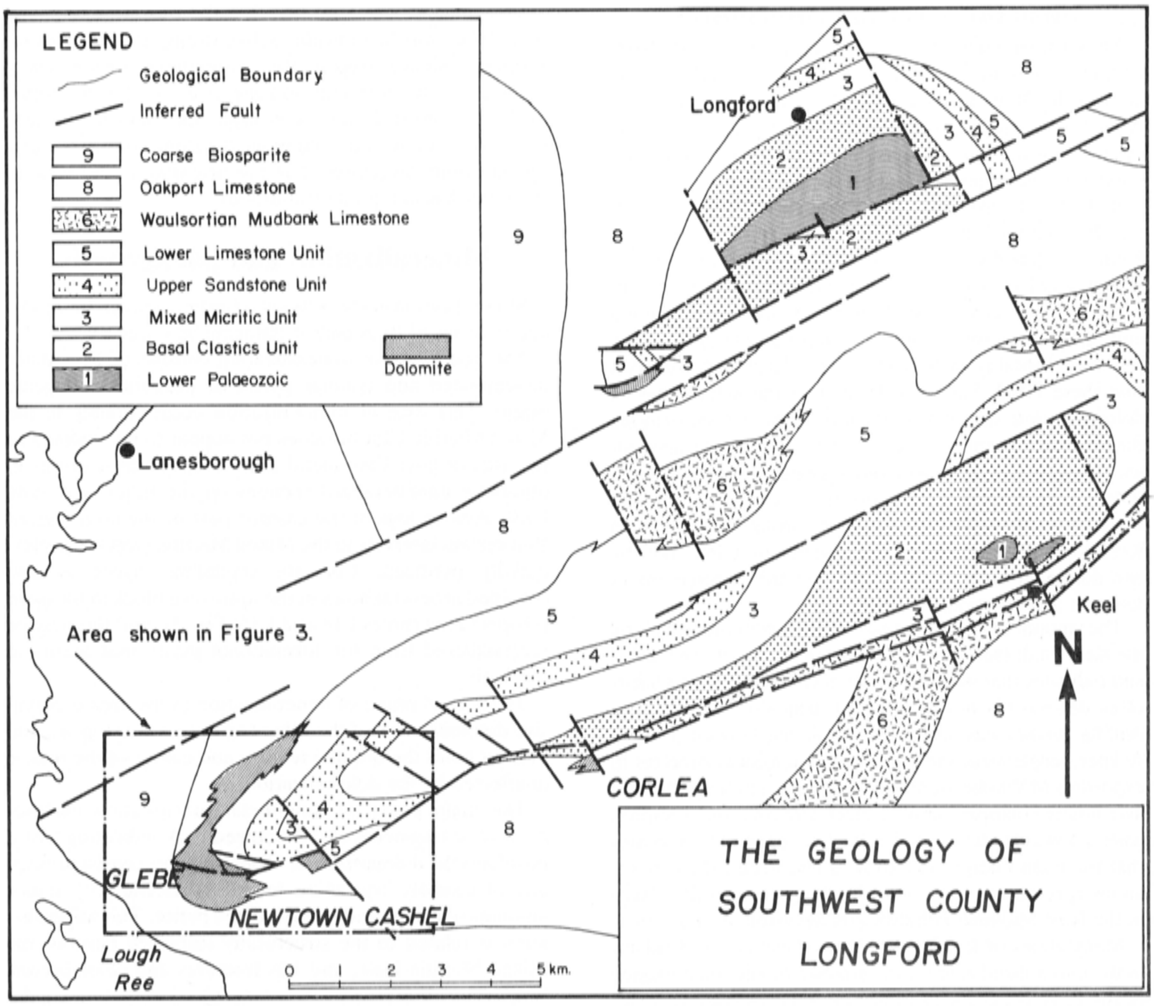

Figure 1. Geology of SW County Longford showing the Keel and Longford Inliers. Note the position of the Keel prospect in relation to Newtown Cashel.

fine-grained, mature character suggests winnowing by wave action, and the common, large-scale, planar cross-stratification and small-scale, lenticular bedding are consistent with a near-shore environment. Quartz-pebble conglomerates from lower in the section may either be due to reworking of pre-existing Old Red Sandstone facies or be indicative of fluvial processes.

The Mixed Micritic Unit is interpreted to have been deposited in very shallow-water conditions. In places it contains micrite with features such as birdseye structures and fine algal lamination suggestive of sabkha deposition, while in other parts, it consists of lensing units of fine-grained sandstone which were deposited in channels. Its small-scale, ripple cross-lamination and flaser bedding suggest tidal action. To the west of Lough Ree, near Roscommon town (15km to WNW), the Unit contains a 30m interval of anhydrite and minor gypsum (see Philcox, 1984). However, since the Mixed Micritic Unit is otherwise lithologically and texturally similar in both areas, the depositional environment in the Newtown Cashel area was probably also periodically evaporitic.

The rocks of the Upper Sandstone Unit are very similar to those in the upper part of the Basal Clastic Unit, and they too are thought to be of nearshore origin. The Unit's gradational upper and lower boundaries suggest it was deposited as a barrier bar or offshore sand bar, whereas a disconformable lower boundary would imply regression and transgression (cf. Ramsbottom, 1973). Both the relative absence of faunal debris and the inferred periodic evaporitic conditions in the underlying micrite unit support the barrier-bar interpretation, and it is therefore concluded that the Mixed Micritic Unit was deposited in a lagoonal environment.

The overlying Lower Limestone sequence, composed predominantly of clean biosparite with a diverse fauna, was clearly deposited in open, shallow shelf, marine conditions having unrestricted circulation. Its argillaceous interbeds are suggestive of periodic influxes of terrigenous material.

The Waulsortian Mudbank Limestone (which occurs at Corlea) is generally believed to have been deposited in shelf conditions in the aphotic zone at depths of 250-300m (Lees et al., 1978).

The depositional environment of the Chadian Pale Micrite Unit is also thought to have been an open shelf, but its predominance of micrite implies relatively quiet conditions. Existing information suggests that mudbanks developed only locally and may well have been governed by local sea-floor slopes adjacent to palaeohighs as suggested by the position of the mudbank (intersected in hole GE1) near the nose of the Inlier.

Structure and unconformities

The structural interpretation in Figure 1 is based on fairly detailed drill-hole, outcrop and geophysical information around the Newtown Cashel end of the Keel Inlier and the western end of the Longford Inlier. Elsewhere, the interpretation is based on scanty outcrops or summary data obtained from other exploration companies.

In the Newtown Cashel area, the main WSW fault bounding the southern margin of the Inlier (termed the Keel Fault) is relatively well controlled by drilling, a change in gravity gradient and a moderate response on IP resistivity profiles. NNW cross-cutting faults are defined by drilling and resistivity profiles, and some have an obvious gravity response (notably at Streamstown). Drill data suggests that these NNW faults are related to the main zones of dolomitization, though karstification in the dolomites along the structures probably account for the low gravity anomalies. These linear gravity features rotate from a northwesterly to a northeasterly trend off the nose of the Inlier, and this change corresponds to a clockwise rotation of the main Keel Fault (Fig. 4). Therefore, it seems probable that the two dominant fault trends in the area are complementary sets that are genetically related.

The amount of vertical displacement is not constant along the Keel Fault (see Fig. 1). Drilling at the Newtown Cashel end indicates that the Keel Fault becomes listric and bifurcates downwards in the prospect area (Fig. 5), whereas drilling further east along the Fault has proved a much steeper, single structure. At Corlea, tensional breccias in exposures of Waulsortian "reef" indicate a pull-apart zone, and detailed mapping shows a clockwise rotation of tension gashes towards the main Fault. This geometry indicates that the main Fault is a dextral, transcurrent, shear zone, an interpretation compatible with the general fault pattern in the Irish Midlands (Phillips and Sevastopulo, this vol.).

Many zones of faulting and loss of section, particularly in the mineralized zones, interpreted from detailed logging of the prospect cores by Philcox (1981), indicate that this general structural picture is probably an oversimplification. These structurally disturbed zones are located beneath the main unconformity (Sections A-A', Fig. 5), strongly suggesting that pre-unconformity faulting is responsible for preserving the thick section of Lower Limestone seen in holes L4 and L6 (see Section A-A', Fig. 5). Rocks immediately beneath the unconformity are intensely fractured in all the cores, and this led earlier workers (unpublished Noranda reports) to interpret the unconformity as a bedding-parallel basal part of a listric fault. However, in core the fractures are high-angle features, and there is little evidence of bedding-plane slip. Moreover, the basal part of the dolomites above the unconformity contains the ghost breccia fragments suggestive of a basal breccia, and this, together with the evidence that the contact is essentially flat-lying and cuts earlier faults, suggests that the unconformity interpretation is more logical. However, future work should seek to verify this interpretation as listric faults can give rise to similar relations (see Shelton, 1984).

Other unconformities may be present in the general Newtown Cashel area. The disconformity interpreted WNW of Corlea is one, but there is no evidence of this disconformity at Newtown Cashel. Another possibility is that Waulsortian "reefs" developed SW of Corlea into the prospect area and have since been cut out by a post-Waulsortian, pre-Pale Micrite Unit unconformity (the Pale Micrite Unit's lower contact is faulted in holes drilled to date). Further work in the area may elucidate whether the Waulsortian was present in the area.

In summary, it is apparent that the western end of the Keel Inlier was tectonically active during the Courceyan. Present evidence suggests that a significant unconformity is present at the termination zone of what later developed as a listric, normal fault. This fault, the main Keel Fault, may have been re-activated along the same zone of the pre-unconformity structures, but the orientation and style of the latter has not been established.

Mineralization and paragenesis

Mineralization in the Newtown Cashel area can be described in terms of its apparent paragenetic sequence.

The first phase of mineralization consists of irregularly disseminated and laminar pyrite of probable authigenic origin. This style of mineralization occurs mainly in the Mixed Micritic Unit but does not appear to be confined to the area of later base-metal mineralization as it occurs in otherwise unmineralized sections on the Inlier (e.g. hole L18). Amoco logs in the eastern part of the area suggest that certain intervals in the Mixed Micritic Unit are preferentially pyritized. Coarsely crystalline pyrite is also recorded in several holes in the upthrown block in the main prospect area (holes L14 and L15, Fig. 3), and this may be recrystallesed from the formational pyrite that occurs in the Unit.

The second phase of mineralization in the area is pervasive dolomitization of the Mixed Micritic Unit (Fig. 6), and in most holes the original texture and colour of the rock is unaffected by the dolomitization.

The main phase of base-metal precipitation encloses brecciated fragments of dolomitized rock indicating that it postdates the dolomitization. The sulphides consist principally of coarsely crystalline brown sphalerite with minor amounts of galena and recrystallized pyrite. This mineralization is related to the structurally disturbed parts of the Mixed Micritic Unit, and fills fractures and coats breccia fragments. More rarely it occurs as spherical spots in argillaceous intervals. Similar sulphides are also disseminated in the upper part of the Basal Clastics Unit and the Lower part of the Upper Sandstone Unit. In these lithologies sulphides have filled available pore spaces and permeability channels such as minor fractures. A similar style of disseminated sulphide mineralization also occurs in the Lower Palaeozoic greywackes (hole L19).

A later generation of orange sphalerite was also deposited during the main phase of sulphide precipitation. It has a spherulitic habit and is probably a variety of high-cadmium sphalerite; assay results record increased Cd values in these zones. High-cadmium sphalerite also occurs at Keel (Slowey, this vol.), and this may indicate a common source for the two deposits.

The next major mineralizing event produced white barite which occurs in fractures, and as rosettes. It usually cross-cuts the sulphides, and there are drillhole intersections of barite up to several metres thick. The association of most of the barite with fractures implies that it was deposited during a late veining episode, and so far, no stratiform-style barite has been discovered like that described at Keel (see Slowey, this vol.).

All of the mineralization described above is confined to the Courceyan Mixed Micritic Unit and to its immediately overlying or underlying units. Aquitaine also discovered sulphide mineralization in the Chadian Pale Micrite Unit further west (hole GE1). The mineralization in this Unit is in brecciated sections of the mudbank facies and occurs as pyrite which rims the cavities and which, in turn, encloses

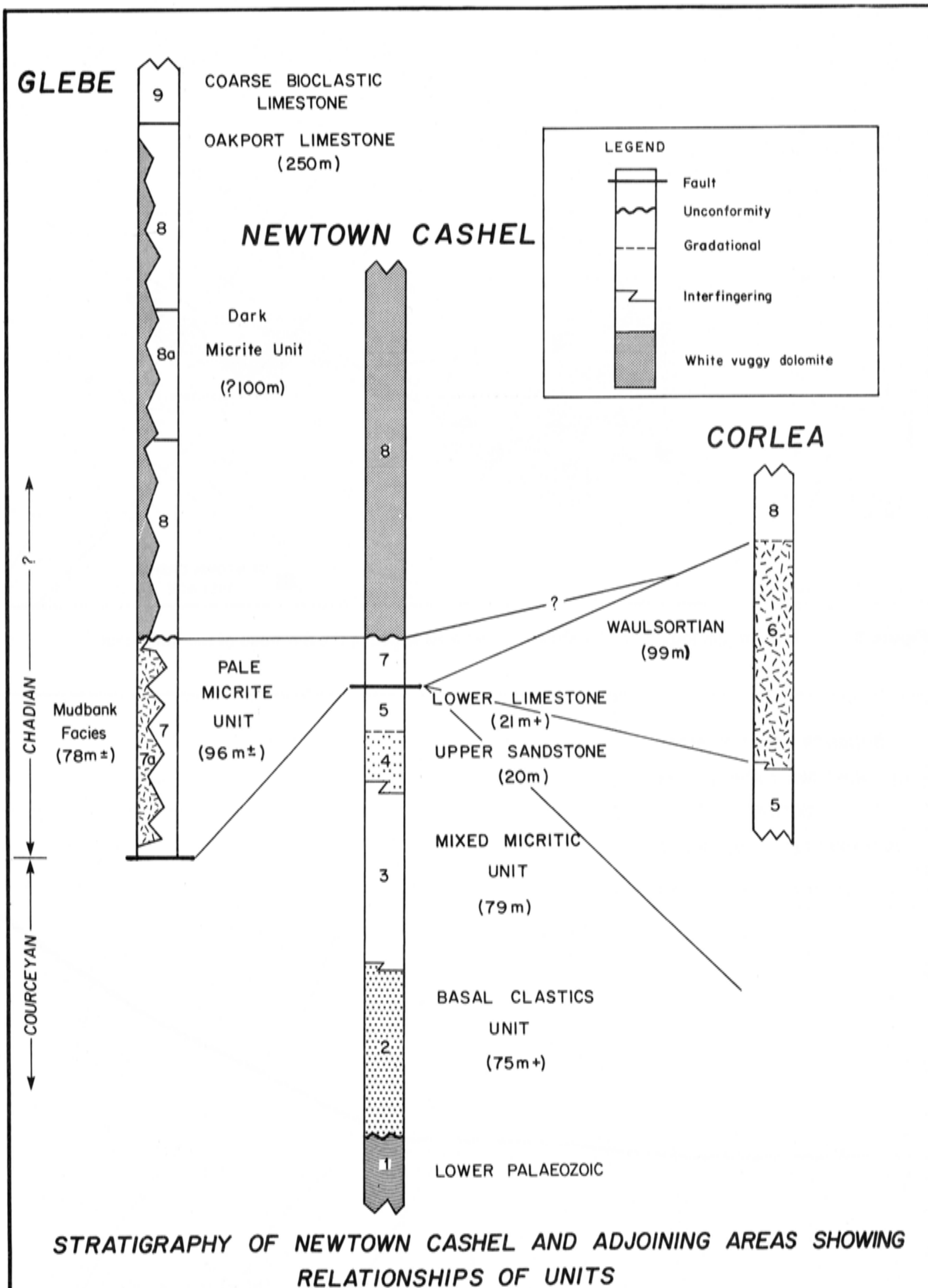

Figure 2. Stratigraphy of Newtown Cashel and adjoining areas showing relations of units. See Figure 1 for location of areas.

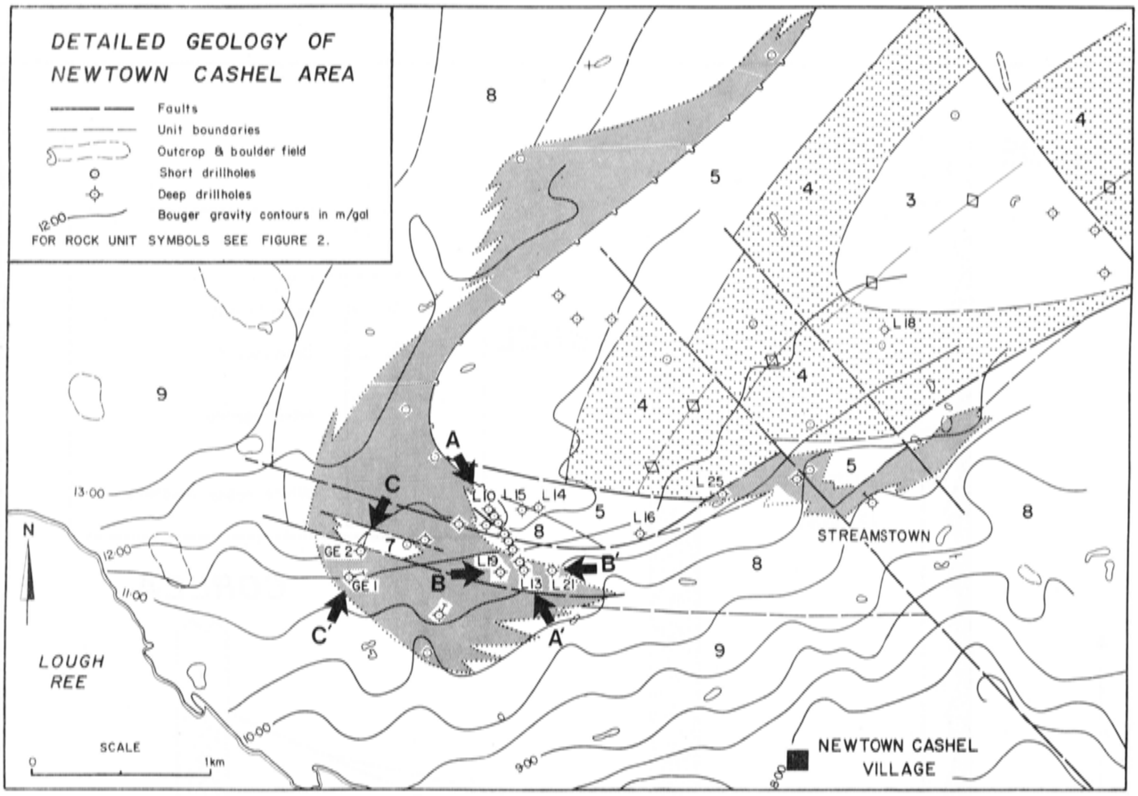

Figure 3. Detailed geology of the Newtown Cashel area showing the SW nose of the Keel Inlier.

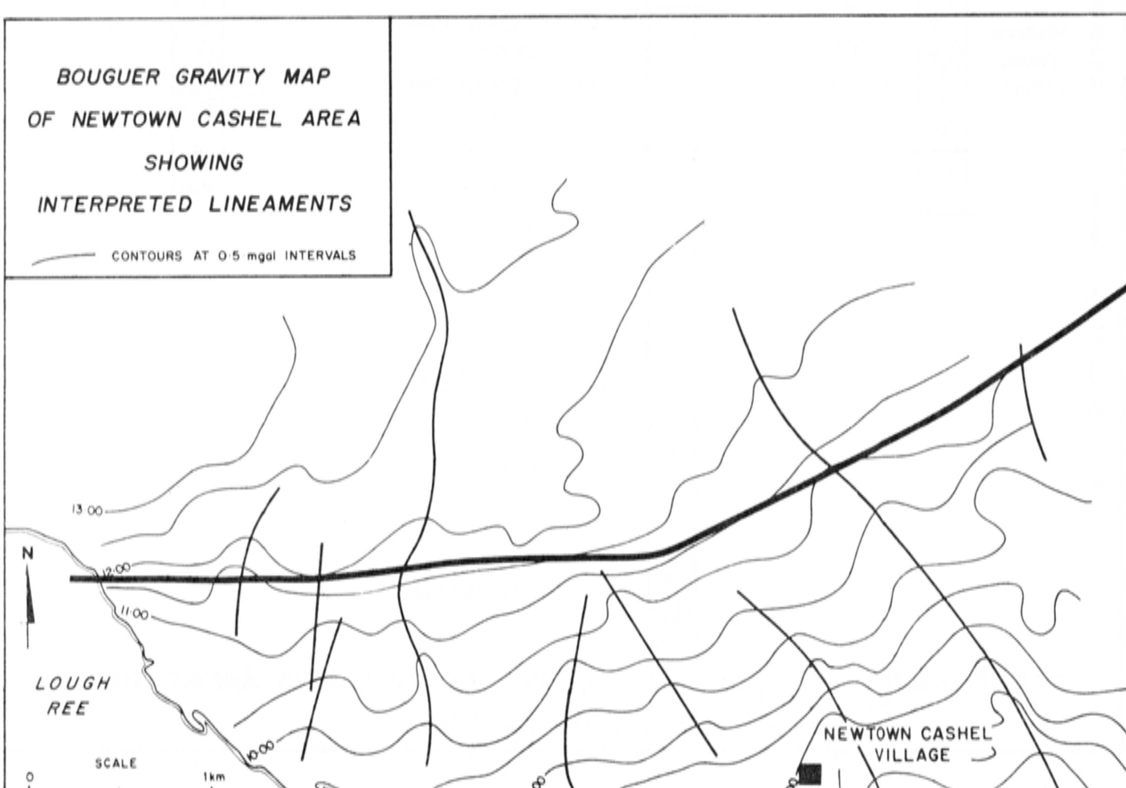

Figure 4. Bouguer gravity map of the Newtown Cashel area showing interpreted lineaments. The thick line represents the change in gravity gradient interpreted as the edge of the inlier. The thin lines are thought to represent cross-faults with an enhanced response due to karstification of the faults.

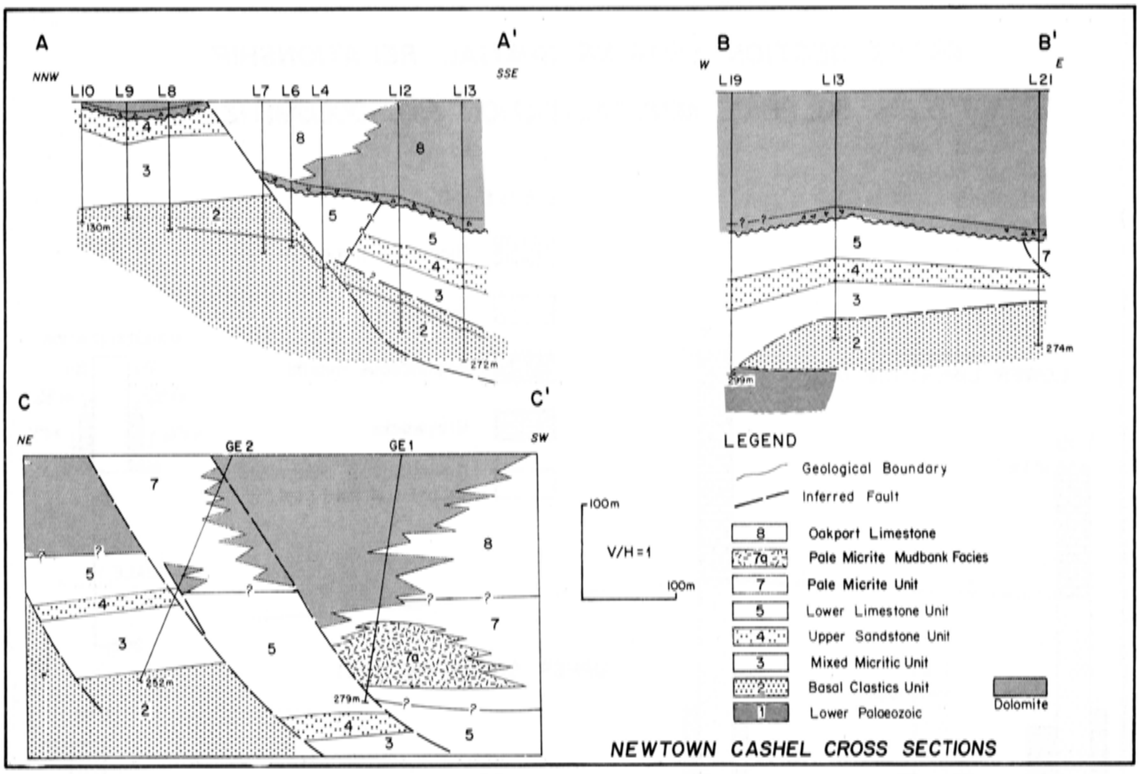

Figure 5. Newtown Cashel cross sections. Borehole positions shown on Figure 3.

coarse sphalerite in a calcite groundmass. The mineralization is restricted to calcite-filled cavities in the breccias and to more isolated cavities in the mudbank facies. It does not occur in stromatactis cavities (these are relatively rare), although it is somewhat similar in style to the "reef"-hosted mineralization at Ballinalack (see Jones and Brand, this vol.).

In general, sulphide mineralization appears to be fracture-controlled and occurs either as obvious fracture or breccia filling or as disseminations in porous lithologies adjacent to fractured parts of the sequence.

The final mineralizing phase produced the widespread, pale orange and white dolomite that has replaced most of the limestones above the inferred unconformity. This dolomite occurs around the nose of the Inlier and structural offsets of the main Keel Fault (e.g. at Streamstown and Corlea; see Fig. 3). The pervasive replacement nature of this dolomite and its apparent structural relationship suggest that it is hydrothermal in origin. The fact that it has more or less only affected rocks above the inferred unconformity suggests that the rocks beneath this contact were effectively lithified prior to dolomitization. However, a few exceptions to this occur adjacent to fault zones where pre-unconformity units have also been dolomitized.

Sequence of events

Before discussing the genetic implications of the mineralization at Newtown Cashel, it is relevent to summarize the sequence of events.

The evidence suggests that the Courceyan units were deposited on Lower Palaeozoic and Devonian basement as part of a slow northwards transgression of a mature shoreline which initially consisted of a lagoon protected by a clastic barrier bar and later developed into an open shelf with mudbanks. These conditions persisted or were repeated in the Chadian as further mudbank and quiet-water facies were deposited.

Local facies changes in the prospect area, particularly in the Chadian Pale Micrite Unit, together with the interpreted local disconformity cutting out the Upper Sandstone Unit on the Inlier (NE of Corlea), suggest that the area was tectonically active during sedimentation. There is, as yet, insufficient evidence to indicate the nature of this synsedimentary tectonism, but it is probable that it was along the same trend as that which later developed into the Keel Fault, and the resultant changes in palaeotopography probably localized the development of Chadian mudbanks.

After deposition of the Courceyan and the Chadian Pale Micrite Unit, these lithologies were lithified prior to the erosion represented by the main unconformity.

The pre-unconformity sequence was then faulted. The fracture control of the sulphide mineralization strongly suggests that the metals were introduced during a phase of tectonism. Since the mineralization tends to occur in sections that contain pre-unconformity faults and since all the mineralization is restricted beneath the unconformity, it seems likely that the metal-bearing brines were introduced during this period of tectonism. It seems reasonable that the unconformity was caused by the same tectonic event. The paragenetic sequence of the mineralization indicates that several pulses of mineralization occurred, and this, in turn, suggests that the tectonism may also have been episodic.

The next event was the deposition of the post-unconformity sequence, but preservation of the sequence is too poor to determine whether these rocks were deposited during a transgression (with a transgressional breccia) or during

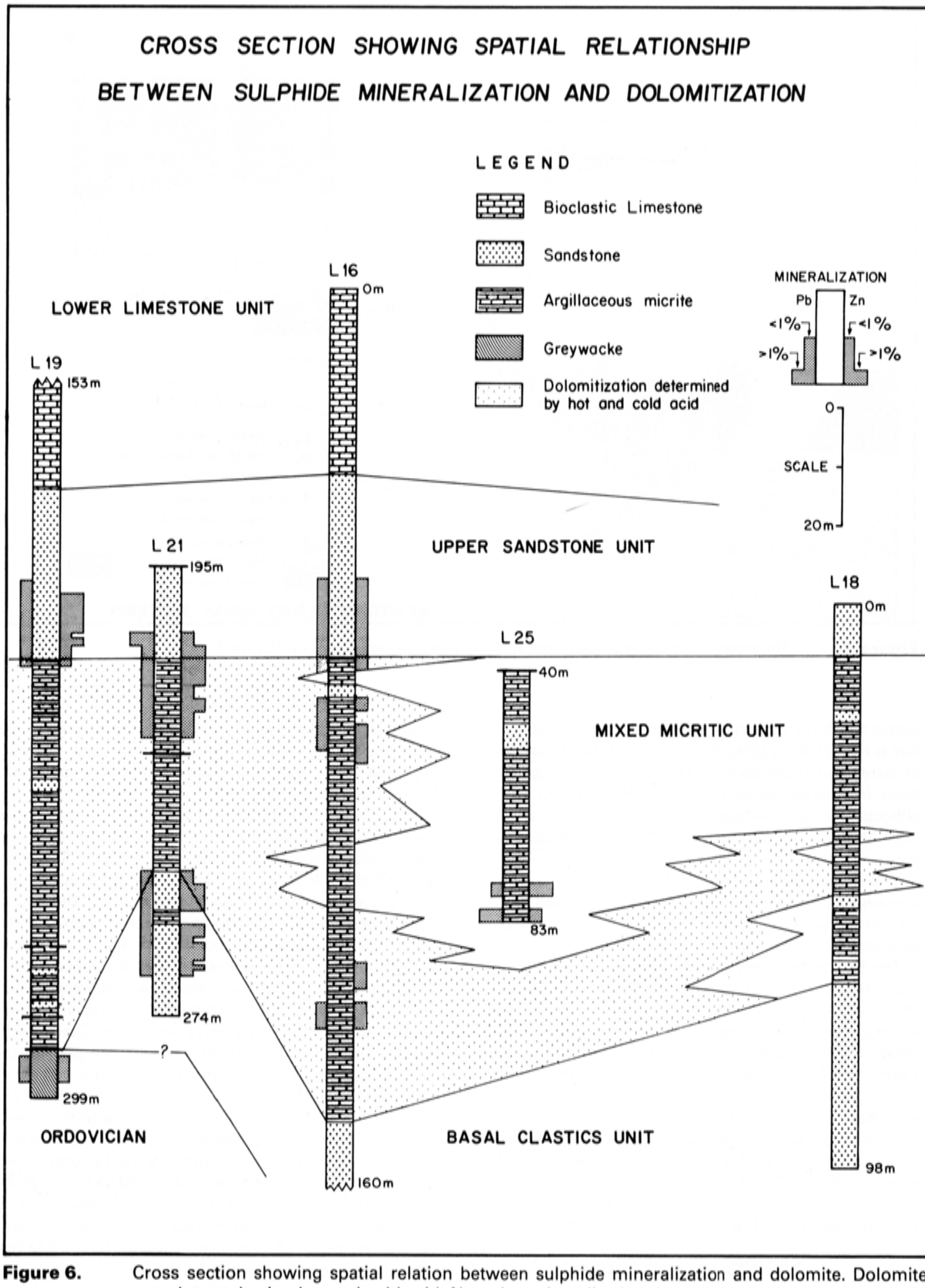

Figure 6. Cross section showing spatial relation between sulphide mineralization and dolomite. Dolomite was detected using hot and cold acid. Note that mineralized carbonate lithologies are pervasively dolomitized to W. Positions of boreholes shown on Figure 3.

rapid local subsidence (with a submarine breccia) caused by the preceding tectonism. Future regional work may clarify the interpretation.

The last recorded significant event was the tectonism that gave rise to the mapped structures, and it is likely that this was Hercynian tectonism which reactivated earlier zones of weakness. The mapped distribution of the white vuggy dolomite suggests that the dolomitizing fluids were introduced along the fractures and faults of this last phase of tectonism.

Conclusions

The mineralization at Newtown Cashel is typical of many of the smaller, fracture-controlled, carbonate-hosted, lead-zinc prospects in the Irish Midlands. However, it also has features in common with some of the larger deposits such as Navan and Silvermines.

Firstly, it occurs in the termination zone of a major dextral transcurrent fault, and this appears to have oblique cross-faults which may be analagous to those described at Silvermines by Taylor and Andrew (1978) and Andrew (this vol.). This repeated fault pattern suggests that such structures have an important role in developing mineral plumbing systems.

Secondly, there is evidence of syn-depositional tectonism in the Newtown Cashel area similar to that at Navan. The Boulder Conglomerate unconformity at Navan (Ashton et al., this vol.) appears to have many features in common with the main unconformity at Newtown Cashel. Both are of similar age, have pre-unconformity faulting, and cut across the mineralized units. However, unlike Navan, the breccia above the unconformity at Newtown Cashel is unmineralized.

Thirdly, the mineralization at Newtown Cashel occurs mainly in the Mixed Micritic Unit which is thought to correlate with part of the main mineralized section at Navan (see Philcox, 1984). This may be genetically significant, as the Mixed Micritic Unit is thought to have been deposited in a lagoonal environment where migrating metal-rich brines may have been introduced into units containing a sufficient remnant supply of reduced sulphur to precipitate their metals.

The similarities between the small deposit at Newtown Cashel and the larger deposits such as Navan and Silvermines suggest that termination zones of major transcurrent faults which generated syn-sedimentary tectonism are preferential sites for the deposition of Irish-style, carbonate-hosted, lead-zinc deposits.

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