An Evaluation of Potential

Pallas Green Property
Co. Limerick & Tipperary, Ireland

Prospecting Licences
635, 636, 2529, 2530, 3268, 3342, 3344, 3431, 3647 and 3908

Prepared for
Minco Plc

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SUMMARY
The Pallas Green prospecting licences (76.4% Xstrata and 23.6% Minco), covering an area of 294 km², are located along the south western boundary of the Irish Midland Orefield, a northeast oriented rectangular area measuring approximately 160 kilometres northeast - southwest by 60 kilometres northwest - southeast. The Irish Midland Orefield has been a major zinc producing area since the mid-1960’s and currently hosts three producing mines, Navan, Lisheen and Galmoy, which in 2005 produced 801,194 tonnes of zinc concentrate and 105,498 tonnes of lead concentrate. The Irish, carbonate hosted, zinc-lead ore bodies, with the exception of Silvermines, and the majority of the major prospects, occur along the boundaries of the ore field which are believed controlled by major basement structure.

The Pallas Green block of prospecting licences is aligned along the poorly explored south western boundary of the ore field and contains a west northwest trending alteration zone, the Pallas Green alteration trend, approximately 25km in length and 2 km in width. This is considered analogous to the Lisheen alteration trend (approximately 20km in length and 2 km in width) which hosts the Lisheen and Galmoy Mines, and which is aligned along the south eastern boundary of the ore field. The Lisheen and Galmoy Mines are located respectively 55 and 60 kilometres northeast of the Pallas Green area and contain (resources plus past production) 33 million tonnes averaging 12.9 percent zinc and 2.4 percent lead.

In contrast to the Lisheen trend, which is at an advanced stage of exploration having been subjected to intense exploration activity since the discovery of Galmoy in 1986, the Pallas Green trend remains 70 percent unexplored with the remaining 30 percent only partially explored by wide spaced diamond drilling, considered the only effective exploration tool. Continuing, aggressive exploration of the alteration trend, primarily by drilling, is strongly recommended. From an exploration point of view, it is instructive to note that the Lisheen cluster of lenses, which are centred just 5km southwest of the Galmoy cluster, was discovered in April 1990 over four years after discovery of Galmoy in February 1986, and that the high grade ‘R’ zone at Galmoy, now a major contributor to production, was only discovered by step-out drilling in 2002, 16 years after initial discovery.
Widely spaced (±800m) step out drilling within the 30 percent of the Pallas Green alteration trend explored to date, has located five massive sulphide lenses. Two small lenses were discovered in 2000 towards the eastern end of the trend at Castlegarde, and three major lenses, Tobermalug, Caherconlish South and Srahane West, within an area of approximately 10 km$^2$ north of the village of Caherconlish, towards the western end of the trend, between 2004 and 2006.

In my opinion, a case can be made that potential for massive sulphide development along the Pallas Green alteration trend might possibly be greater than that of the Lisheen trend. This assessment of potential is based on:

- A success rate, in terms of massive sulphide ‘hits’, at least as good, and possibly better, than would be expected from a similar density of drill holes along the Lisheen trend.
- Similarity in geological setting, similarity in host rocks (the mineralization along both trends occurs as variably sized lenses hosted by black matrix breccias), and similarity in geometry, style and grade of high grade massive sulphide mineralization
- Location on the ore field boundary
- A more widespread distribution, both laterally and vertically, of black matrix breccia (host to mineralization) and sulphide at Pallas Green compared to Lisheen. Along the Lisheen trend many, if not most drill holes sited between the massive sulphide lenses are devoid of black matrix breccia and sulphides. This contrasts with drill holes outside of the massive sulphide lenses along the Pallas Green trend which, almost without exception, have intersected black matrix breccia and sulphides, suggesting a wider development of the host breccia systems and a more aggressive hydrothermal system at Pallas Green than at Lisheen

In conclusion, given the very early stage of exploration at Pallas Green, where 70 percent of the alteration trend remains unexplored by drilling and the remaining 30 percent only partially explored, the potential for massive sulphide discovery along the Pallas Green trend is considered at least as high as that of the Lisheen trend, which hosts two known major clusters of massive sulphide lenses which comprise the Lisheen and Galmoy Mines.
One such cluster of lenses could be at the early stage of definition at Caherconlish. It is possible that the Tobermalug drilling lies at the northern edge or periphery of a major or ‘principal’ lens. Such lenses at Lisheen and Galmoy contain core areas of exceptionally high grade and width, especially along their southern boundaries adjacent to major, east northeast to east west striking ‘controlling’ faults. The Caherconlish inferred resource has a lower average grade than the Lisheen and Galmoy ore bodies, possibly reflecting the absence, so far, of high grade ‘core’ zones at Caherconlish. An analogous ‘controlling’ structure is believed to lie approximately 800m to the south of current drilling at Tobermalug. Within the Caherconlish area, in the ground between the known massive sulphide lenses, only a few, widely spaced (approximately 0.5 to 1.5 kilometres apart) drill holes have been completed. These have consistently intersected alteration, host breccias and sulphide mineralization, indicating considerable potential to both extend the known massive sulphide lenses and discover additional lenses.

In my opinion, the presence of alteration, black matrix breccias and sulphide mineralization in nearly all of the drill holes completed to date elsewhere along the entire length of the alteration trend suggests considerable potential for the identification of additional clusters of massive sulphide lenses on the licence block.
INTRODUCTION

The Midland Orefield of Ireland is a major producer of zinc and lead concentrates with currently three major producing mines. These are the orebodies at Lisheen and Galmoy operated respectively by Anglo American and Lundin Mining, with which the mineralization currently being outlined on the Pallas Green property is directly analogous, and the world-class Navan orebody operated by New Boliden Tara Mines and in production since 1977.

<table>
<thead>
<tr>
<th>Mine</th>
<th>Zinc Concentrate</th>
<th>Lead Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tonnes</td>
<td>Zn%</td>
</tr>
<tr>
<td>Navan</td>
<td>358,563</td>
<td>54.6</td>
</tr>
<tr>
<td>Lisheen</td>
<td>299,000</td>
<td>53.35</td>
</tr>
<tr>
<td>Galmoy</td>
<td>143,631</td>
<td>51.73</td>
</tr>
<tr>
<td>Total</td>
<td>801,194</td>
<td>53.6</td>
</tr>
</tbody>
</table>

(Source: Dept. of Communications, Marine and Natural Resources, State Mining and Prospecting Facilities and Industry News, 1st May, 2006)

The zinc-lead mineralization discovered to date on the Pallas Green licence block is analogous to the mineralization at Lisheen and Galmoy- Table 2, in terms of style, geological setting and geological associations, and considerable potential is believed to exist for ore bodies of Lisheen-Galmoy type on the Pallas Green licence block.

The Pallas Green license block is centred respectively, 55 and 65 kilometres southwest of Lisheen and Galmoy, 30 kilometres south of the past producing zinc mine at Silvermines (17.7mt averaging 6.4%Zn and 2.5%Pb: IAEG 1986), and 15 kilometres west northwest of the past producing Gortdrum copper mine which produced 3.8mt averaging 1.2%Cu- Steed 1986.

The Midland Orefield of Ireland remains one of the most prospective areas in the world for carbonate hosted zinc-lead base metal deposits, over the years attracting many of the world’s major mining companies. The area represents a mature exploration play with the potential for world-class deposits, especially at depth below the reach of geochemical and geophysical techniques.
TABLE 2

Production, reserves and resources at Lisheen and Galmoy, December 31st 2005

<table>
<thead>
<tr>
<th></th>
<th>m/t</th>
<th>Zn%</th>
<th>Pb%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lisheen</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>8.04</td>
<td>11.69</td>
<td>2.2</td>
</tr>
<tr>
<td>Reserves</td>
<td>10.58</td>
<td>14.04</td>
<td>2.16</td>
</tr>
<tr>
<td>Resources</td>
<td>3.99</td>
<td>13.71</td>
<td>2.23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22.61</strong></td>
<td><strong>13.1</strong></td>
<td><strong>2.2</strong></td>
</tr>
<tr>
<td><strong>Galmoy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>5.05</td>
<td>11.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Reserves</td>
<td>3.55</td>
<td>14.7</td>
<td>4.1</td>
</tr>
<tr>
<td>Resources</td>
<td>1.61</td>
<td>10.9</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10.21</strong></td>
<td><strong>12.5</strong></td>
<td><strong>2.9</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32.82</strong></td>
<td><strong>12.9</strong></td>
<td><strong>2.4</strong></td>
</tr>
</tbody>
</table>

(Source: Dept. of Communications, Marine and Natural Resources, State Mining and Prospecting Facilities and Industry News, 1st May, 2006)

Exploration in Ireland over the past forty five years has produced a substantial body of geological experience and data to assist ongoing exploration.

PALLAS GREEN PROPERTY

Property, Location, Ownership and History

The Pallas Green Block, in which Minco holds a 23.6% interest (the remaining 76.4% is held by Xstrata), is located between Limerick city and Tipperary town and was acquired by Minco in the mid 1990’s - Figure 2. The Xstrata interest has been earned through exploration expenditure under the terms of a joint venture agreement signed in 1998 (originally by Noranda). Xstrata is project operator and have engaged consultants BRG to manage the project with Dave Blaney as project manager and David Stewart as project geologist. Combined they have over 30 years of Irish exploration experience, including first hand experience with Lisheen-Galmoy type deposits.

The license block consists of ten contiguous prospecting licenses, 635; 636, 2529, 2530, 3268, 3342, 3344, 3431, 3647 and 3908, covering an area of 294km² Figure 2.
In September 1998, Minco entered into a joint venture agreement with Noranda covering the Pallas Green licence block. Under the joint venture agreement, as amended and expanded in November 1999 Xstrata (initially through Noranda and then Falconbridge) has acquired a 76.4% interest in the license block for a cumulative expenditure of €3.4 million. The joint venture has completed an airborne survey, surface geochemical and geophysical surveys, 139 diamond drill holes - 53 on Pl.636, 16 on Pl. 2529, 2 on Pl. 2530, 24 on Pl. 3342, 3 on Pl. 3344, 34 on Pl. 3268, 5 on Pl. 3647, 1 on Pl. 635 and 1 on Pl. 3908 – and extensive lithogeochemical sampling of drill core, supervised and interpreted by Gonzalo Gonzalez, consultant, designed to detect mineralogical and geochemical halos associated with the massive sulphide lenses and to correlate drill hole sections. Results to date indicate that this technique can identify vectors to assist exploration.

Approximately 55 shallow drill holes were completed by Gortdrum Mines Limited in the 1970’s on licences 3268 and the western part of 3647, which is underlain by Waulsortian Reef. These outlined two major areas of low grade, breccia hosted zinc-lead mineralization at Longford West and Carreg Beg.
Mineral Rights

Irish Prospecting Licenses are based on a Townland system, with each license containing a differing number of adjoining townlands. A typical license covers an area of approximately 35km². The townland boundaries are marked on the six-inch series of ordnance survey maps.

It is not the intent of this report to detail the finer points of Irish Mining Law but a brief synopsis of the salient points and historic precedent is as follows. Surface rights for mining operations in Ireland have historically been negotiated with the landowners. Over a large proportion of the country the Mineral Rights are held by the State and the government will issue a Mining License to the holder of the Prospecting License after a successful application has been made. The terms of the License are negotiable and the Government tends to take a royalty and a set dead rent. In a minority of cases the landowner may own the mineral rights and a Mining Lease must be obtained that will compensate the mineral rights owner.

Access

At Pallas Green, as in most parts of central Ireland, there is an extensive minor road infrastructure which allows easy access. Ireland enjoys a temperate environment and there is access to the field throughout the year. The only proviso is that during the winter months the area is prone to extended periods of heavy rain resulting in water-logged ground and associated flooding. At these times, normally during the winter or early spring, companies may choose to limit access to avoid undue damage to agricultural land and minimize compensation payments to the landowner, which are normally minimal.

REGIONAL GEOLOGY-THE MIDLAND OREFIELD OF IRELAND

Geological Setting

The Midland Orefield appears to form a coherent geological unit with well defined boundaries along which occur major changes in fold pattern, strike of fold axes and faults, and stratigraphy (thickness and facies changes).
The orebodies, with the exception of Silvermines, and the majority of the major prospects are localized along the boundaries of the orefield. The Midland Orefield is rectangular, oriented northeast southwest, approximately 160 kilometers in length, northeast to southwest, and 60 kilometers in width. The Tynagh-Ballinalack Trend forms the north western boundary, the Navan Trend the north eastern boundary, the Rathdowney Trend the south eastern boundary, and the Limerick Trend, along which the Pallas Green property is aligned, the south western boundary.

Deep seated basement structure is believed to underlie each of these trends and the impact of movement along these is seen in the geological record as:

- Regional geophysical trends-magnetics and gravity
- Regional structural trends.
- Long lived regional stratigraphic trends. Post Lower Carboniferous stratigraphic trends can be seen following the eastward projection of both the Navan and Limerick trends in Britain and Europe, where they appear to form the northern and southern boundaries of the Anglo-Brabant Massif.
A coherent pattern of en echelon, northeast striking perianticlinal folds is developed throughout the orefield. This fold pattern ends abruptly at the northwestern and southeastern boundaries of the orefield. The strike of northeast-southwest striking fold axes and associated east northeast striking faults changes across the northeastern and southwestern boundaries, from northeast within the orefield to east northeast to the northeast and southwest of the orefield.

The Pallas Green licence block lies along a major west northwest oriented, regional structural trend, the Limerick Trend, one of a number of such trends which appear to define the orefield boundaries and with which the major Irish zinc mines and deposits appear to be associated. The Limerick Trend, which defines the southwestern boundary of the orefield, can be traced in Ireland from Galway Bay in the northwest to the Waterford coast in the southeast. It is believed that the continuation of this trend can be seen in Pembrokeshire, South Wales, from where it can be traced to southeast England and into Europe as the southern boundary of the Anglo-Brabant Massif - Figure 3. It is postulated that this trend relates to deep seated, fundamental basement structure. A zone of alteration, associated with ‘Black Matrix Breccia’ development, and widespread zinc-lead mineralization, both ‘high or ore grade’ lenses of massive sulphide and extensive low grade sulphide mineralization have been encountered in drilling over recent years throughout the licence block, localised within the approximately 2km wide alteration zone following or superimposed upon the underlying basement structural trend. This alteration trend is analogous to the Lisheen alteration Trend with which the
clusters of massive sulphide bodies which comprise the Lisheen and Galmoy orebodies are associated. Seventy percent of the Pallas Green alteration Trend remains unexplored.

**Irish Carbonate-Hosted Deposit Types**

‘Irish Type’ carbonate hosted zinc/lead deposits exhibit considerable variation in geometry, essentially reflecting the geometry of the host stratigraphy upon which they are superimposed. This variation results in categorisation of the individual Irish deposits as either MVT or Sedex.

Within the southeastern quadrant of the Midland Orefield, which includes the Pallas Green block, the economic zinc-lead deposits replace irregular, stratiform breccia bodies developed at or close to the base of the massive, unbedded, Waulsortian Formation, a biostomal reef micrite. Black Matrix Breccias are peculiar to the southeastern quadrant of the orefield, and host the massive sulphide lenses worked at Lisheen, Galmoy and Silvermines and the massive sulphide lenses currently being explored on the Pallas Green licence block.

These breccias consist of angular, highly irregular clasts of dark grey dolomite in a very dark grey to nearly black matrix. Breccia textures range from clast to matrix supported and the clast colour from pale to dark grey. The matrix of the breccia is composed of ferroan to non-ferroan dolomite with minor disseminated iron sulphides.

**Photograph 1**: Typical Black Matrix Breccias with sulphide ‘clasts’, mainly sphalerite. MN636-47 and MN636-48, Tobermalug.
Centimetric partings and lenses of black argillaceous sediment are commonly seen within the breccias. The principal lenses of massive sulphides replace these breccias and, at Lisheen and Galmoy, are often coextensive with them. Breccia formation clearly pre-dates the sulphide mineralisation and ‘regional’ dolomitisation. Ore related dolomite, however, is reported cutting and replacing early ‘regional’ dolomites at Silvermines and Lisheen. This hydrothermal alteration forms numerous hairline veinlets of fine grained ferroan dolomite. Lithogeochemical studies indicated an excess of magnesium within the Reef close to the main zones of mineralisation, suggesting the presence of magnesite. The magnesium enrichment passes laterally to an iron rich ferroan dolomite and then to a halo of more distal manganese enriched dolomite.

The Black Matrix Breccias have been widely interpreted as hydrothermal in origin, and genetically related to the sulphide mineralisation. The mineralization, however, clearly replaces the various breccia fabrics and thus post dates breccia formation. The age relationships between breccia formation and sulphide replacement are unclear. An alternative interpretation, preferred by the author, is that the Black Matrix Breccias are karstic in origin, the result of uplift and erosion of the reef complex during deposition which was localized by the underlying basement structure. This same structure later localised the alteration and mineralization. An erosional-karstic origin for the black matrix breccias is supported by the presence of:

- thin interbeds of quartz sandstone within the reef micrites, spatially associated with the breccias, in several holes drilled on the Pallas Green block, and
- In the Caherconlish area, rapid thinning of the massive reef, possibly, a result of localized erosion and facies changes—see Figure 4 below.
It is postulated that tectonic movements centred along the Limerick trend during sedimentation of the Waulsortian, a result of movements along the underlying basement structural zone, resulted in localized non-deposition, erosion and deep karstification with production of the Black Matrix Breccias. Uplift was not evenly distributed, but localized adjacent to small, syn-sedimentary fault structures arranged en echelon in the recent sediments above the basement structure. These structures could also have localized ground water circulation and karst breccia development.

Figure 4-Stratigraphic section of selected drill holes in the Caherconlish area. Datum=base of reef.
Figure 5—Proposed model for the formation of Reef facies within the alteration trend.

The larger, or principal stratiform lenses of high grade, massive sulphide within Lisheen and Galmoy are typically wedge shaped, ranging from <30m thick close to east northeast ‘controlling’ faults, to centimetric scale bands of massive sulphide around the periphery of the lens, with the massive sulphide the result of preferential replacement of stratiform Black Matrix Breccia units within the Reef. Lenses peripheral to these larger, or principal lenses tend to be more irregular in shape, commonly elongate and possibly related to northwest trending breccia/fault zones. Over a horizontal distance of just a few metres, several metres of massive sulphide can terminate abruptly, replaced by massive, unmineralised reef micrite. The upper and lower contacts between massive sulphides and host rocks can be either extremely sharp, with sulphides terminating abruptly along a stylolite or thin shale laminae—see photograph below, or gradational with massive sulphide passing into disseminated or vein controlled sulphides over several metres.


**Photograph 2**: Upper contact to the ‘R’ zone at Galmoy, with massive sulphide terminating against a thin, shale parting.

**PROPERTY GEOLOGY (Figure 6)**

**History of Exploration**

Mineralisation within the alteration tend was initially discovered at Coonagh Castle on prospecting license 3268 in 1972, by Gortdrum Mines Limited. This consisted of low grade disseminated zinc and lead mineralization within sub-reef limestones in the immediate footwall of the Coonagh Fault, possibly a ‘root system’ of a Waulsortian Reef hosted deposit since eroded. The most extensive mineralization was hosted by massive calcarenite beds 35 to 60m above the base of the Argillaceous Bioclastic Limestone, the same horizon as the Lower Dolomite mineralisation at Silvermines. Subsequent drilling by Gortdrum in the 1970’s discovered extensive areas of low grade disseminated pyrite/sphalerite/galena mineralisation (2-5% zinc with minor lead over true thicknesses of up to 23m) at Longford West and Carreg Beg. This mineralization was associated with black matrix breccias and re-brecciated black matrix breccia containing altered igneous fragments (polymict breccia) within the basal part of the Waulsortian Reef.

Following discovery of the Galmoy and Lisheen orebodies, and recognition of the Lisheen Trend, the concept of a structurally bounded Midland Orefield was developed with mineralization localized along the boundaries. The Limerick Trend was identified on the basis of regional stratigraphy, structure and geophysical trends, and the licenses 635, 636,
An aeromagnetic survey flown by the Billiton-Minco Joint Venture in 1998 covering licenses, 2530, 3268, 3342 and 3647, outlined areas of Lower Volcanics (Knockroe Volcanic Formation) with anomalously low magnetic susceptibility. These lay largely within PL 2530, but extended into PL 3268. It was postulated that the low magnetic susceptibility was due to hydrothermal alteration of the basaltic volcanics, and part of a system similar to that which had produced the dolomitisation of the Waulsortian along the Lisheen Trend to the northeast. In early 2000, the Minco-Noranda joint venture re-flew the aeromagnetic survey, extending coverage to the west-northwest, to cover prospecting licenses 2529, 636 and 635. This survey demonstrated that basaltic volcanics with anomalously low magnetic susceptibilities extended to the west northwest onto prospecting licenses 2529, 636 and 635.

The Minco-Noranda joint venture undertook a programme of detailed mapping, petrographic examination, and lithogeochemical sampling in the spring and summer of 2000 (Tennant, S.C., 2000). Samples of Lower Volcanic rocks were collected from within and outside the magnetic anomaly and analyses demonstrated that the low magnetic susceptibility anomalies within the Lower Volcanics was indeed due to hydrothermal alteration. It was shown that the loss of magnetic susceptibility was due to pervasive alteration of the volcanics consisting of chloritisation (Mg-Fe mass gain plus loss of alkalis and silica and more minor sodium and potassium). This crosscuts the entire Lower Volcanic succession. In outcrop, the volcanics are often strikingly altered with destruction of primary textures. In some areas the chloritisation is accompanied by additions of zinc. The altered volcanic rocks are less resistant to erosion and produce low lying areas in contrast to the resistant unaltered volcanics which form a series of pronounced hills outlining the Limerick syncline. The lithogeochemistry and petrography of this study provided the first direct evidence for the Pallas Green alteration trend.

Stratigraphy (See inset-geology map, Figure 6)

The geology of this region is dominated by Lower Carboniferous Limestones and extrusive volcanics. Strata dip gently to the south at between 10° to 25° towards the axis of the east-west orientated Limerick Syncline. The oldest Carboniferous rocks (the Lower Limestone Shales) consist of shallow water marine, peritidal, micrites/oolites/grainstones inter-bedded with fine grained siliciclastics and argillaceous shales. The subsequent carbonate facies, the
Lower Limestone Shales, reflect steadily increasing water depths, consisting of a well bedded succession of fully marine, shaly calcarenite and dark calcareous shales. The Argillaceous Bioclastic Limestone is in turn conformably overlain by the Waulsortian limestone, a succession of massive, clean, essentially unbedded, biostromal reef micrites.

Within the license block the Waulsortian appears to be approximately 400m in thickness. Within parts of the Caherconlish area, however, the reef is strongly attenuated, thinning rapidly from around 400mm to as little as 128m over a distance of around 2 kilometres between the Caherconlish and Tobermalug prospects, see Figure 4. It is clear from structure contouring of base of reef that the attenuation of the massive reef in the Caherconlish area is not structural but stratigraphic, and probably the result of localized facies changes and erosion. Mapping indicates a thinning of the reef outcrop for up to 6km to the east of the Caherconlish area suggesting that the attenuation demonstrated in the Caherconlish area could extend eastwards.

Black Matrix Breccias have been demonstrated present within the basal 100 to 200m of the Waulsortian reef throughout the alteration trend, over a distance of approximately 20km. These breccias occur as irregularly shaped, stratiform lenses consisting of re-worked fragments of Waulsortian reef associated with thinly laminated, carbonate rich, black shales. These are directly comparable to the Black Matrix Breccias that host the Lisheen, Galmoy and Silvermines orebodies. In two holes, thin siliciclastic sandstones and have been intersected providing support to the hypothesis that these breccias could be the result of karstification, the result of local uplift and erosion during deposition of the Waulsortian Reef, along the line of the Limerick Trend – see Figure 5.

Within the alteration trend the Waulsortian micrites are pervasively dolomitised. The supra reef, Chadian stratigraphy includes thick intervals of basaltic volcanics built up around a number of volcanic centers, and is thus very different from the Chadian elsewhere in Ireland where reef is overlain by a thick succession of bedded limestones. The volcanic centres appear to be aligned along the Limerick Trend. The Lower Volcanics are a complex association of volcaniclastics, lavas and intrusives of the alkali basalt-trachyte suite with marked variations in thickness around the syncline controlled by lithofacies (550 m to lees than 250 m). The thicker areas are dominated by volcaniclastic rocks, whilst lava dominates the thinner, more laterally persistent, portions of the formation. The Upper Volcanics of
Knockseefin form a 500m thick pile of fresh looking, sparsely olivine phyric, lavas with strikingly scoriaceous and blocky margins plus trains of vesicles indicating flow movement. The outcrop width of the Herbertstown Limestone Formation varies considerably. The Namurian rests with angular unconformity upon the Dromkeen Limestone Formation along the northern limb of the Limerick syncline and upon the older Upper Volcanics along the southern limb. The unconformity demonstrates uplift, tilting and erosion, possibly localized along the Limerick Trend and comparable to the postulated, earlier and more restricted erosion of the Waulsortian.

Numerous basaltic intrusions occur in the area of the alteration trend as dykes, sills and plugs. Larger plugs outcrop northeast of the license block at Knockbrack and Maddyboy, and south of the license block as an east-west line of intrusives. Diamond drilling between Gortdrum and Longford West, along the eastern extension of the Pallas Green alteration trend, has revealed the presence of a large number of mafic dykes, ranging in width from a few centimeters to several meters within the sub-reef succession. At Gortdrum these dykes strike between 070° and 080°, paralleling a regional joint direction. These dykes are probably aligned en echelon along the alteration trend, following the alignment of the volcanic centres believed controlled by the basement structure underlying the Limerick Trend. The majority of dykes and sills are altered, with many intensely altered to a mixture of clay minerals and dolomite. These were referred to as Buff Alteration Zones (BAZ) at Gortdrum, where they were strongly mineralized within and adjacent to the ore zones. Outside of the immediate area of the Gortdrum mineralisation, these altered intrusives are commonly pyritised, with fine disseminated pyrite approaching 20 to 30 percent in places. The Oola lead mine, operated in the 19th century, was hosted by an altered, east-west striking dyke, or dykes. Within the unbedded, massive Waulsortian, which does not have the well developed east-west joint system of the underlying, bedded limestones, intrusions are more irregular in orientation and less continuous, presumably lensy, and drilling indicates that many could be flat lying, sill-like bodies. An altered, mineralised sill within the Waulsortian, 50m to 80m above the base-of reef, can be traced in drilling over a strike length of 1 km at Carreg Beg on license 3268. This might be intruded along an erosion surface within the otherwise, massive, unbedded Waulsortian.

Within the ore zones at Gortdrum, altered dykes were intensely mineralised. For example, disrupted sections of a large breccia dyke, consisting 20 to 30 percent of altered igneous fragments and 70 to 80 percent of wall rock fragments, were the focus for extremely high
grade (20 percent plus) copper mineralisation within the eastern, structural “wedge” orebody at Gortdrum (Steed, 1986). Dykes and plugs of intrusive breccia are commonly intersected in drill core within the sub-reef succession. Dykes range in width from a few centimeters to fifteen meters and many follow earlier basaltic intrusions and, in these cases, contain fragments of both the earlier, dyke rock and fragments of the adjacent sedimentary wall rocks. Breccia dykes without a basaltic precursor, containing just fragments of sediment, are also present in the area, such as the wide, weakly mineralised (pyrtite, sphalerite and galena) dyke at Cauteen – PL. 3647– which, on the basis of a resistivity anomaly, could have an east-west strike length of 1.2km. The breccia textures seen in the Pallas area range from shatter breccia to carbonate matrix breccias, in which some vertical movement of fragments has occurred, to flow breccias in which significant movement and attrition of fragments has occurred, for example at Cauteen. At Cauteen and within the Gortdrum mine, vertical transport of up to 40m could be demonstrated. Where intensely developed, flow breccias consist of angular to sub-rounded fragments – often with irregular, fretted outline – of variable composition, suspended in a finer grained, ‘rock flour’ matrix of the same composition. Many of the black matrix breccias intersected within the Pallas Green alteration trend have been intruded and re-brecciated and now include fragments of highly altered basic intrusive. Such breccias were present within the Longford West/Carreg Beg drilling in the 1970’s on PL’s 3647 and 3268. More recently such breccias have been intersected on PL 3344 and on PL 636, at Tobermalug in the Caherconlish area, where they have been referred to as ‘polymict’ breccias. The polymict breccias at Longford West - Carreg Beg and Tobermalug are well mineralized, replaced by pyrite, sphalerite and galena. At Tobermalug these breccias contain massive, ‘ore-grade’ mineralization. The pyrite-sphalerite-galena mineralization within these ‘polmict’ breccias and intensely altered dykes post dates the intrusions and formation of the breccias, many of which are suspected related to the Upper Volcanics which are Late Asbian or Brigantian in age.

The breccia lithologies associated with ‘igneous free’ breccias, such as the Cauteen dyke and some of the breccia bodies in and adjacent to the Gortdrum Mine, appear very similar to those seen in the breccia bodies hosting the mineralization at Harbeton Bridge, along the northeastern continuation of the Lisheen Trend.
Structure

The Pallas Green licences are aligned along the Pallas Green alteration trend, or Limerick structural trend, which is expressed in this area as west northwest striking, regional flexure in the strike of fold axes and east northeast striking faults. It is probable that the complex fold-fault pattern developed on the property reflects accommodation of this flexure. The Pallas Green licences encompass a major transition in fold style: to the northeast lies the complex perianticlinal fold systems of the Slieve Phelim, Silvermines and Devilsbit Mountains; to the southwest the structure is dominated by the east-west trending Limerick syncline and, centred on Limerick City, the northeast trending Castleconnel syncline. Between these two synclines, bounded by the Clare Fault to the north and Ballyneety Fault to the south, lies an independently folded block containing the westerly ‘pinch-out’ of the Slieve Phelim-Silvermines-Devilsbit perianticlinal structure. The Ballyneety and Clare faults converge to the west and presumably intersect to the west of the licence block, eliminating the fault block. Abrupt changes in the strike of bedding occur to the north and south of the fault block, across the Ballyneety and Clare faults, indicating that faulting and folding developed together and that differential folding took place across these major east-northeast faults. The Caherconlish area lies within this structural block.

Five east-northeast trending fault zones spaced 4 to 6 km apart and including the Ballyneety and Clare Faults, cut the west-northwest alteration trend on the Pallas Green licences. The Coonagh, Dromkeen, Ballyneety and Clare faults can be mapped in the Slieve Phelim to the northeast of the license block as topographic features and as offsets of the base of the Old Red Sandstone, which has generally been well located by mapping.

All of the major, carbonate hosted Irish deposits are located in the hangingwall, or north of such structure, which appear to provide the primary structural control to mineralization. Typically, major changes in fold pattern occur across these structures, which have ‘compartmentalised’ the folding, indicating fault and folds evolved together. Major east northeast faults are ‘offset’ dextrally by ‘northwesterly’ (NNW to WNW) trending cross faults. Within the various deposits, northwesterly structure plays an important role in localizing mineralisation.

The Coonagh Fault is exposed below Coonagh Castle, where it dips at 65° to the north. Drilling at Coonagh Castle has demonstrated a reverse throw on the Coonagh Fault of 100m.
The Ballysteen Limestone on the northern, up-thrown, hangingwall side of the fault contains low-grade zinc-lead-pyrite mineralisation. The best grades, 12.2m averaging 0.91% zinc and lead, were located within the massive calcarenites at the base of the Middle Pale Limestone, at the base of the Ballysteen Formation. This is the time stratigraphic equivalent of the Lower Dolomite horizon at Silvermines, which hosts the Lower Dolomite “orebody”. In the Shandangan area, 3.0 km to the west of Coonagh Castle, the reverse throw on the fault appears to have increased to between 400m and 500m. The dips of the Dromkeen, Ballyneety and Clare Faults are unknown but are most likely 40° to 65° to the north, in keeping with the other east-northeast striking faults in the Irish Midlands for which dips are known.

Mapping of faults in areas underlain by limestone, which are low lying and generally covered by thick glacial deposits, is generally impossible. On the Pallas Green licences the volcanic rocks outside of the alteration trend, tend to form higher ground, and here topography in many cases appears to reflect structure. The throw on the Ballyneety and Clare Faults varies as a result of differential folding on either side of the faults. In the vicinity of the anomalous Pallas Green geophysical trend, the throw on the Clare Fault is estimated at 200m, down to the north, and on the Ballyneety Fault at around 500m, down to the north.