CLEMENTS

Background information:

Mine Name: Clements

Mine District: Connemara

Alternative Names:
Carrowgarriff

Elements of interest:
Pb, Ag, Cu, Zn

Project Prefix: CLEM-

County:	**Townland:**	**Grid Reference:**
Galway	Carrowgarriff	E99410, N251843

Clements mine site is on a steep hillside in the Partry Mountains, overlooking the northwestern shore of Lough Corrib, 3km east of Maum Bridge on the Maum – Clonbur road. It was the last mine to be developed in Connemara, in 1907, and it is the most substantial mine site in the district.

Geology and Mineralization

The bedrock consists of graphitic pelites, semi-pelites, psammites and minor amphibolites of the Dalradian Cornamona Formation (Reynolds *et al*. 1990). The main mine workings were excavated along a northwest-trending shear zone with the richest mineralization consisting of a massive replacement of impure marble by sulphide, developed in places around cross-cutting veins. The main sulphides were galena (PbS) and pyrite (FeS_2) with lesser sphalerite (ZnS) and chalcopyrite ($CuFeS_2$) (Reynolds *et al.* 1990).

Production and Mining History

Clements may have been worked as early as 1800 (Cole 1922) but is not recorded subsequently in the 19th century as a working mine. The mine as it is today (Fig. 1) was developed in 1907 by Glasgow-based Clements Lead Mines Ltd. (Reynolds *et al*. 1990). The mine manager, Bacon, described a rich lode, 1.2 – 4.5m wide, half of it composed of argentiferous galena with an average grade of 44% Pb and 5 oz/ton (176 g/tonne) of silver. The lode was excavated by a still-extant northwest-trending opencast over a length of 120m (Fig. 1; photo, right). A cross-cut adit was developed 51m below the summit of the hill but failed to intersect the main Pb-Ag lode although it did cut a 1.2m-wide Cu-Pb lode as well as several minor quartz-sulphide veins (Reynolds *et al*. 1990). Further trials were undertaken to the north of

the main excavation but without success. A crushing plant (photo, below left) was constructed, driven by water drawn from the nearby stream, and ore was transported from the workings via trams that were hauled on an endless ropeway. A pier was built on the lake below and the ore was taken by boat to Galway.

By November 1907, 900 tonnes of high-grade lead ore had been raised in the previous three months, with production averaging 36 tonnes per day. The mine manager anticipated increasing production to 13,600 tonnes per annum (Reynolds *et al*. 1990). However, there is no further record of production in 1907 and less than two tonnes were recorded for 1908 (Cole 1922). Some 6.5 tonnes of ore, hand-picked from the dumps, were shipped to Chester in 1918. The grades were 63% Pb and 248 g/tonne Ag for the ore selected for further processing. There are records (GSI Open File records) of further prospecting on the site in the 1950s and 1970s but there has been no further production since 1908.

Site Description and Environmental Setting

The modern Clements site covers over 5 ha of mixed grassland, heathland and exposed bedrock on the steep hillside above Lough Corrib (Fig. 1). The grassland on the lower slopes is part of a working farm and is used for cattle grazing. The site is incised by a mountain stream that was used as a source of water to power the crusher house. The remains of this building stand on the lower-most part of the site. From there the trace of the tramway runs uphill for 250m via several spoil heaps to the area of opencast and underground mining. Two adits and one shaft were identified on the so-called Middle Level. The adit immediately east of the stream (photo, right) was driven below the opencast in order to intersect the lode. It runs east then south to emerge as the second adit on the southeastern side of the site (Fig. 1). The shaft has collapsed but a 2m-deep hollow marks its position at the western end of the opencast. No trace was found of the adit driven on the Lower Level from the bank of the stream while the exploratory adit driven on the Upper Level is still open. The opencast is the most striking feature on the site and consists of a 140m-long trench, up to 7m deep and 5m wide.

Seven separate waste heaps have been defined (Fig. 1). Some are entirely bare (photo, above) but most have at least some grass cover. The waste in heaps SP01, SP04 and SP06 is typically red-brown in colour, showing abundant oxidation of grains. Both SP01 and SP06 contain fine-grained material that appears to have undergone crushing. In contrast, the

remaining heaps are relatively coarse-grained, with a fresh, grey colour. Table 1 provides an estimate of the volume of solid waste on the site.

Table. 1 Area and volume of waste heaps at Clements

Waste ID	Area (m^2)	Volume (m^3)
CLEM-SP01	343	343
CLEM-SP02	3290	1098
CLEM-SP03	1954	1041
CLEM-SP04	2626	1677
CLEM-SP05	264	972
CLEM-SP06	6	60
CLEM-SP07	1096	936

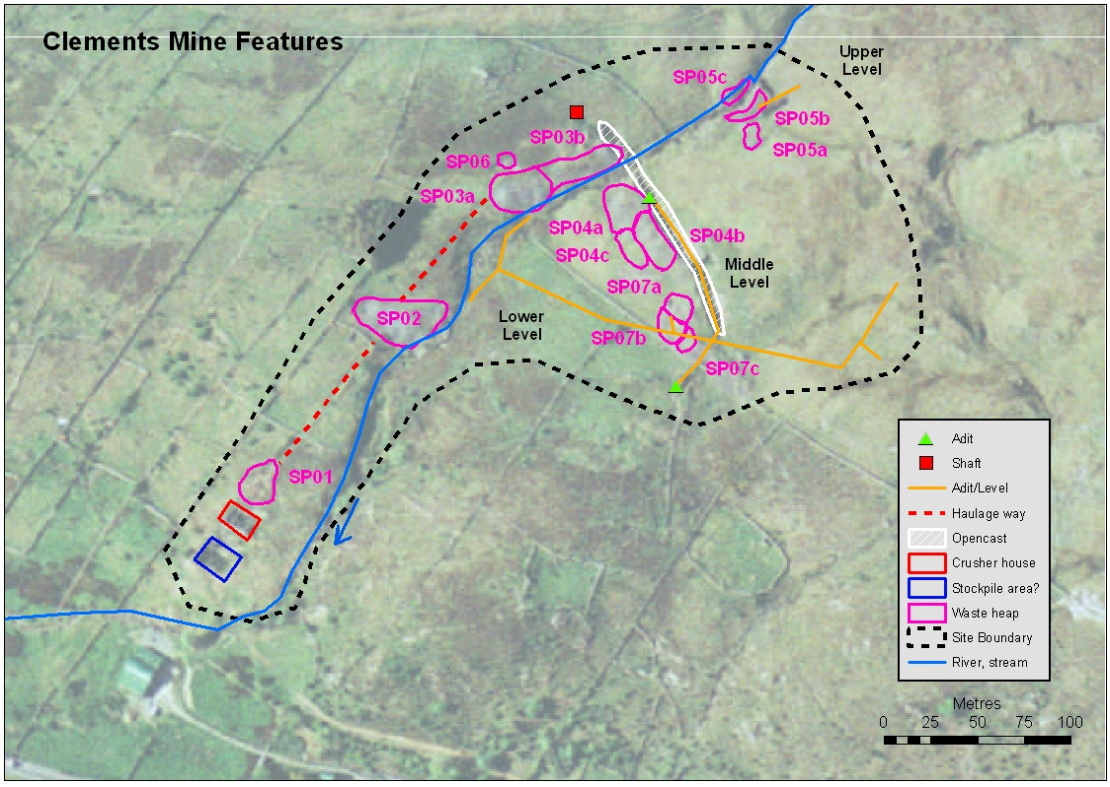

Fig. 1 Clements: mine features

Geochemical assessment

1. Surface water

The stream was sampled upstream and downstream of the mine site in November 2007 (Fig. 2). Most of solid waste heaps are located close to the stream bank but no mine water discharge was observed entering the stream. Table 2 summarizes the results for total metal concentrations. There is a small measured difference in composition for some elements upstream and downstream of the mine, with the downstream sample having higher Pb, Zn, Cu, Cr and Al. The differences measured appear significant, i.e. downstream concentration more than three times the upstream concentration, in the case of Zn and Cr, but only Zn exceeds the Draft EC Surface Water Regulation standard (100 µg/l) in the downstream sample. The measured Pb concentration in both the upstream and the downstream samples (8 µg/l and 13 µg/l, respectively) exceed the Draft EC Surface Water Regulation standard (7.2 µg/l) for surface water. There is no corresponding difference in dissolved metal concentrations between upstream and downstream samples and measured concentrations of dissolved metals are lower than measured total concentrations (e.g. Pb: 4 µg/l upstream and downstream; Zn, Cu, Cr < 1 µg/l upstream and downstream). This raises the possibility that the measured total concentrations may reflect analytical variation rather than true sampling variation. The pH ranges between 6.04 (upstream) and 6.32 while EC is very low (0.05-0.07 mS/cm).

Table. 2: Summary data for surface water analyses, Clements

µg/l	Pb(tot)	Zn(tot)	Cu(tot)	Cr(tot)	Al(tot)
W002 (Upstream)	8	41	15	4	370
W001 (Downstream)	13	161	27	16	425

2. Groundwater

No groundwater sources were sampled. A leachate extract for dissolved metals of a composite sample from SP04 contained 3057 µg/l Pb, 36 µg/l Zn, 12 µg/l Cu, 15 µg/l Ba and 28 µg/ Al. Leachate from a composite sample from SP02 and SP03 had 9 µg/l Pb and 8 µg/l Zn. While the latter concentrations do not breach Drinking Water standards, those in the leachate from SP04 do. The solid waste at Clements thus has the potential to contaminate groundwater in the vicinity of the mine site.

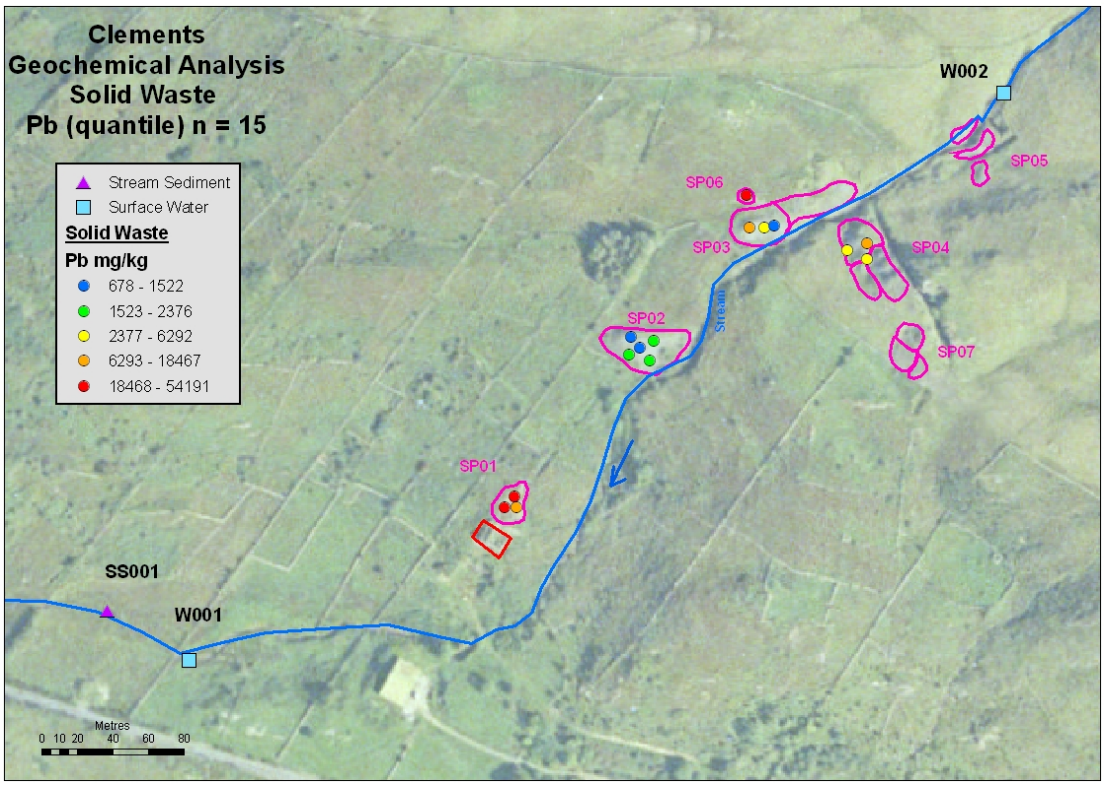

Fig. 2 Clements: Sampling points and solid waste geochemistry (Pb)

3. Stream sediments

The stream flowing through the Clements site is an immature mountain stream that flows over bedrock in its upper reaches where no sediment was available for collection. Thus only one, downstream, sample was collected at Clements (Fig. 2). Table 3 shows the measured concentrations for some elements in the Clements sample as well as the median concentrations for the same elements in sediments overlying the Dalradian rocks of the Inishowen peninsula in Co. Donegal. The Clements sample contained relatively high concentrations of Pb, Zn, Cu, As, Ni and Ba, well above those expected in sediments in streams draining unmineralized Dalradian bedrock. The concentration of Fe (21.57%) and Mn (6.14%) was also very high and adsorption of metals by Fe-Mn hydroxides may have influenced the concentration of elements such as Zn, As and Ba. However, it seems likely that mining has been the major contributor to the composition of stream sediments at Clements.

Table. 3: Summary statistics for stream sediment analyses, Clements

mg/kg	Pb	Zn	Cu	As	Ni	Ba
SS001 (d/s)	1971	1755	95	245	557	1003
Inishowen (median)*	50	184	41	17	43	650

*** Stream sediments from streams overlying the Dalradian of Inishowen, Donegal (O'Connor *et* al. 1988).**

4. Solid Waste

Waste heaps SP01, SP02, SP03, SP04 and SP06 were analysed *in situ* by XRF (Fig. 2). The measured Pb concentration ranged from 678 mg/kg to 5.4%, with a median of 5621 mg/kg (Table 4). Other metals such Zn, Cu, As, Fe and Mn were also present in relatively high concentrations, at least in some samples, and Ag was also detected in a few cases. The distribution of Pb in the solid waste shows a clear correlation between oxidized waste (SP01, SP04, SP06) and high Pb concentrations with the coarser, fresher grey spoil (SP02, SP03) having generally lower Pb concentrations.

Table. 4: Summary statistics for field XRF solid waste analyses, Clements

mg/kg	Pb	Zn	Cu	As	Ag	Fe	Mn
n	15	15	15	15	15	15	15
Minimum	678	383	0.0	0.000	0.0	29559	777
Maximum	54191	1702	790	1494	83	423768	10089
Median	5621	914	298	282	0.0	59482	2993
Mean	10549	1020	329	445	17	134379	3334

0.0 = < detection limit

5. HMS-IRC Site Score

Table 5: HMS-IRC Site Scores, Clements

Waste	SP01	SP02	SP03	SP04	SP05
1. Hazard Score	57	17	16	72	15
2. Pathway Score					
Groundwater	4.31	1.31	1.26	5.24	1.19
Surface Water	14.03	5.47	5.24	22.78	4.90
Air	0.02	0.02	0.02	0.16	0.00
Direct Contact	0.06	0.07	0.03	0.25	0.00
Direct Contact (livestock)					
3. Site Score	**18**	**7**	**7**	**28**	**6**

Waste	SP06	SP07	Stream Sediment	Total
1. Hazard Score	56	16	43	292
2. Pathway Score				
Groundwater	4.31	1.23		18.85
Surface Water	14.03	2.80		69.25
Air	0.00	0.00		0.21
Direct Contact	0.00	0.00		0.41
Direct Contact (livestock)			8.61	8.61
3. Site Score	**18**	**4**	**9**	**97**

The total HMS-IRC Site Score for Clements is 97, the highest score for any Class V site. Of this, solid waste contributes 88 and stream sediments 9. For the purposes of scoring the solid waste, median concentrations were calculated for the analyses made on SP01, SP04 and SP06, on the one hand, and SP02 and SP03 on the other, representing oxidized and relatively fresh waste, respectively. The waste in SP01, SP04 and SP06 is also more metal-rich. The medians thus calculated were applied to each heap. SP05 and SP07 were scored using the medians calculated for SP02 and SP03.

The site scores for the solid waste heaps reflect the metal concentrations of the oxidized and fresh grey, less mineralized waste, with the latter having significantly lower scores. The full downstream extent of stream sediment contamination is not known. There is around 250m of stream between the area of the crusher building and the sampling site but the sediments may have high metal concentrations further downstream of the site. Thus the score of 9 may well be a minimum for this source.

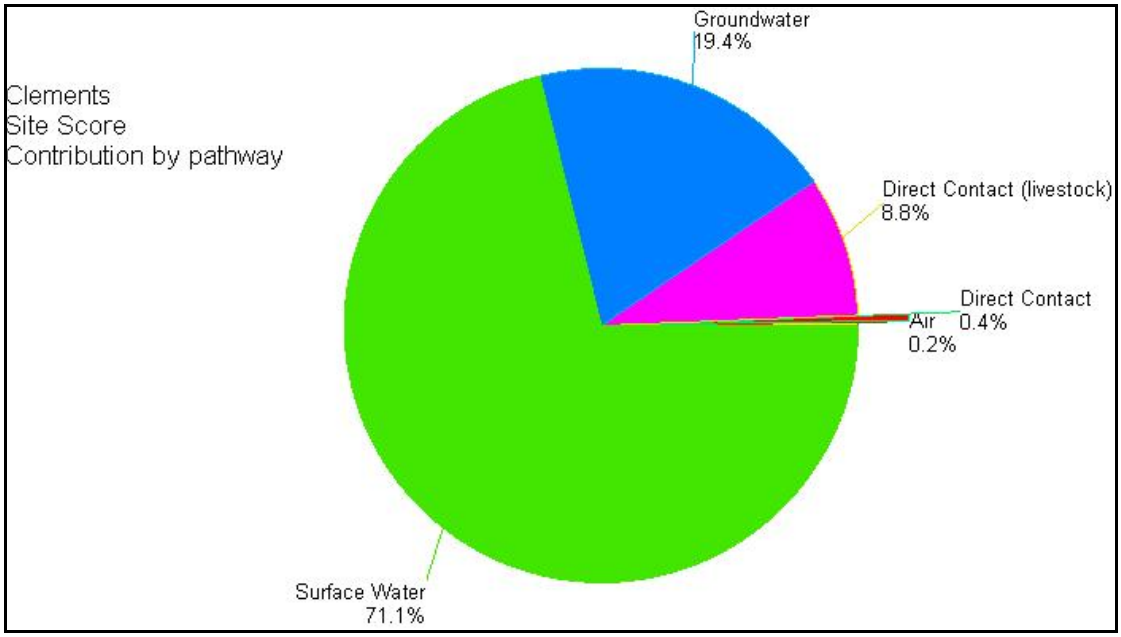

Fig. 3 HMS-IRC Site Score, Clements: contribution by waste source

Fig. 3 shows the site score according to pathway. The proximity of the stream, the poor quality of the aquifer and low density of wells in the area, contribute to a high surface water to groundwater pathway ratio (71.1% to 19.4%). Low population density helps minimize the direct contact pathway for humans (0.4%) and the grass cover and coarse grain size of much of the solid waste result in a negligible air pathway score (0.2%). The stream was fenced off where it crossed grazing land on the farm below the mine site but parts of it are accessible to sheep, at least, in its lower reaches.

6. Geochemical overview and conclusions

Solid waste heaps at Clements comprise both oxidized, metal-rich waste and relatively fresh waste with a high concentration of unmineralized material. All waste has relatively high concentrations of Pb, with the maximum concentration (5.4%) recorded in crushing waste. The median Pb value of all the solid waste analysed was 5621 mg/kg (0.56%). A surface water sample taken downstream of the mine had 161 µg/l Zn and 13 µg/l Pb (total metal), in excess of the Draft EC Surface Water Regulation standard (100 µg/l and 7.2 µg/l, respectively). Upstream concentrations were 41 and 8 µg/l, respectively. These values suggest some impact from the mine waste. However, caution is required as dissolved metal concentrations show no similar pattern. One stream sediment sample downstream of the mine had high concentrations of Pb (1971 mg/kg), Zn (1755 mg/kg), As (245 mg/kg) and Ni (557 mg/kg).

References

Cole, G. A. J. 1922. Memoir and Map of Localities of Minerals of Economic Importance and Metalliferous Mines in Ireland. Memoirs of the Geological Survey of Ireland.

Odell, N.E. (undated) Report on the Clements Mine Carrowgarriff Townland, Co. Galway. GSI Mine Records.

Reynolds, N., McArdle, P., Farrell, L.P.C., Flegg, A.M. (1986). Mineral localities in the Dalradian and associated igneous rocks of Connemara, Co. Galway. Geological Survey of Ireland, Report Series RS 86/3 (Mineral Resources).