

Lough Graney GWB: Summary of Initial Characterisation.

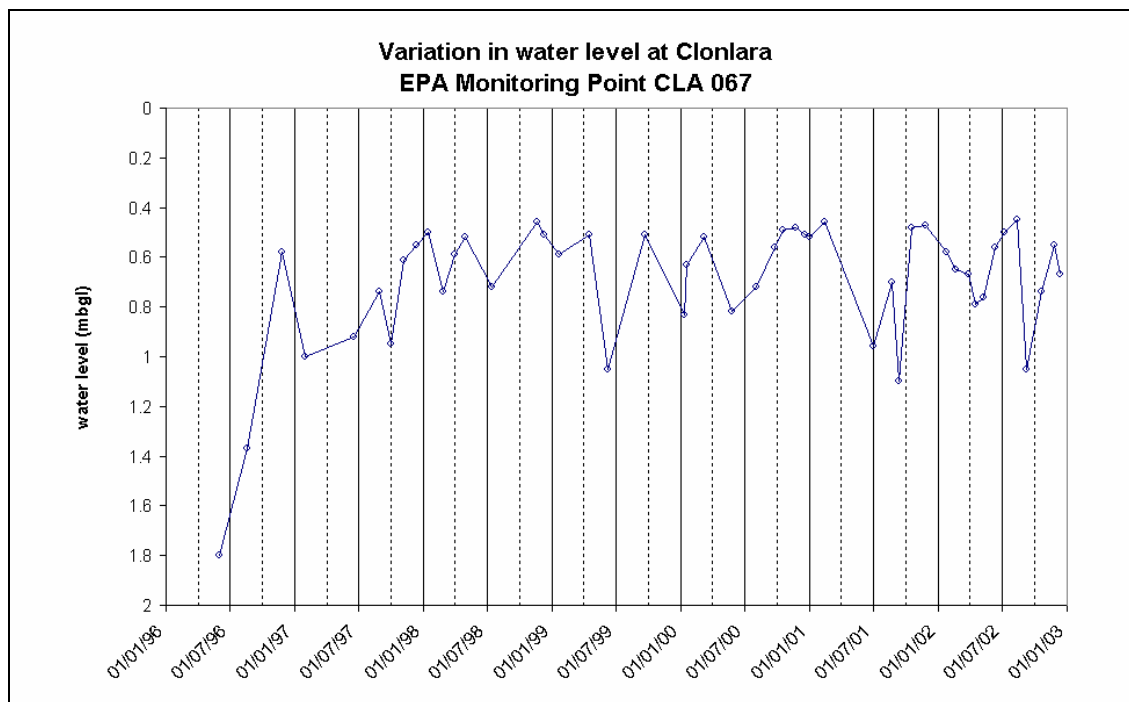
Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystems	Area (km ²)
25 - Graney Catchment Clare and Galway Co. Co.'s	Rivers: Bleach, Graney, Drumandoora, Corra, Cloghaun, Ayle, Ardclony, Broadford, Blackwater, Mountrice, Shannon, Caher, Ballyteige, Black. Streams: Scarrif, Glenmora Wood. Loughs: Loughanoran, Lahardaun, Lackagh, Graney, Maghera, Leaghort, Ea, Nacally, Ross, Derryaneal, Derryeaghera, Carter's, Dromore, Errinagh, Cragroe, Rosslara, Loughanilloon, Clooncoose, Maryfort, Craggaunkeel, Castle, Meelagh, Agannygal, Loughaniddaun, Shanemore's, Atorick, Derg, Keel, O'Grady, Fir.	Loughanilloon Bog (001020), Loughatorick South Bog (000308), Lough Derg (000011), Lough O'Grady (001019), Pollagoona Bog (002126), Lough Graney Woods (001714), Glendree Bog (001912).	449
Topography	The groundwater body has an irregular outline, is larger at the northern end, and is orientated N-S. Elevation within the GWB ranges from less than 20 mAOD in the very south of the GWB, and about 30 mAOD along the shore of Lough Derg (along the SE boundary) to 532 mAOD at the Moylusa peak of the Slieve Bernagh, in the west of the GWB. The topography ranges from mountainous in areas underlain by the resistant sandstones and mudstones of the Devonian Old Red Sandstones and Silurian rocks, where elevations are generally >80 mAOD, to flat-lying in areas underlain by impure limestones, where elevations are typically 40-60 mAOD. Ground elevation decreases towards the centre of the GWB, which is underlain by less resistant impure limestones, and, in the southern half of the GWB, it decreases eastwards towards Lough Derg. In the northern half of the GWB, the River Graney occupies a deep valley, whose base is at about 50 mAOD. River flows are predominantly southwards and eastwards, to Lough Derg and the lower reach of the River Shannon.		
	Geology and Aquifers	Aquifer categories	In the northern third of the GWB, aquifers are predominantly PI : Poor aquifers which are generally unproductive except for local zones. In the remainder of the GWB, aquifers are predominantly LI : Locally important aquifers which are moderately productive only in local zones, with areas underlain by Silurian rocks classified as PI . The Devonian Old Red Sandstones are classified as PI in the northern zone and LI in the southern zone of this GWB.
Main aquifer lithologies		Devonian Old Red Sandstones and Silurian Metasediments and Volcanics occupy nearly all of the northern and southern parts of the GWB; there are small areas of Ordovician Metasediments and Volcanics in these areas also. A thin (3.5 km) E-W orientated band of Dinantian Lower Impure Limestones and Dinantian (early) Sandstones, Limestones and Shales separates the northern and southern upland areas. These rock unit groups are also found along the southern border and in the SE of the GWB adjacent to Lough Derg. In the west of the GWB, Dinantian Pure Unbedded Limestones outcrop and subcrop.	
Key structures		The major structures affecting the distribution of rock types and hence aquifer types are large anticlinal and synclinal folds, and major faults. The older and more resistant rocks that form the Aughty and Bernagh Mountains occur within the cores of the anticlines that are found in the south and north of the GWB. The younger impure and pure limestones are found preserved in the cores of the synclines, particularly in the low land in the centre of the GWB. Fold axes trend E-W and ENE-WSW. There are several major faults with the same orientation as the fold axes crossing the GWB. The most notable is the Knockshigowna Fault, which runs along a sinuous, offset trace from Slieve Bernagh to east of Tullamore in Co. Offaly more than 60 km away. In the Slieve Bernagh there are several NW-SE and NE-SW trending faults cross-cutting the main ENE-WSW structural grain. Compression during the folding also caused fracturing and jointing of the rocks.	
Key properties		In the Silurian rock unit in the Slieve Felim mountains to the south of this GWB, a site investigation undertaken for a proposed landfill found that permeabilities in the top 30 m of rock ranged from 0.00036 to 0.76 m/d. A zone of higher permeability, 150-200 m wide, 12-14 m deep and 2.2 km long was delineated on the site. The transmissivity estimated for this zone was 27-82 m ² /d (Deakin, Daly and Coxon, 1998). At Templeberry, in the Nenagh GWB, early time pumping test data indicate a transmissivity of around 5 m ² /d. The high transmissivity quoted is probably only attained in limited circumstances. For the ORS in this GWB, there are no data. In the northern area of the GWB, transmissivities will be very similar to the Silurian aquifers. In the southern zone of the GWB, transmissivities will be low, but mainly better than in the Silurian rocks, especially toward junction with the Dinantian (early) Sandstones, Shales and Limestones. Within the Dinantian Lower Impure Limestones, transmissivities are likely to be in the range 2-20 m ² /d, with most values at the lower end of the range. Dinantian (early) Sandstones, Shales and Limestones aquifer properties are less good than this. A pumping test in the Dinantian Pure Unbedded Limestones (Waulsortian limestones) at Shinrone in west Co. Offaly indicated a transmissivity of approximately 27 m ² /d. At Tulla in Co. Clare, transmissivity in the same rock unit is estimated as 13 m ² /d. These values are probably at the middle to higher end of the range. Within all rock units, storativities are low. Groundwater gradients in the upland areas may be steep (up to 0.1). In lower-lying areas, groundwater gradients on the order of 0.01 to 0.04 may be the norm. Storativities in all rocks are low. Porosity values of approximately 0.015 are likely to be representative of the ORS and Lower Impure Limestones in Co. Clare. (data sources: Rock Unit Group Aquifer Chapters, GWPS Reports, Source reports, see references)	

	Thickness	The Silurian, ORS, Ordovician and Dinantian Lower Impure Limestone aquifers are more than several hundreds of metres thick at their maximum. However, permeability tends to decrease rapidly with depth. Most flow occurs in the upper ≤ 15 m, in the zone that comprises a weathered layer and a connected fracture zone below this, although deeper flows may occur along faults or significant fractures. The maximum thickness of Dinantian (early) Sandstones, Shales and Limestones is less than 100 m. Again, groundwater flow is confined to the top 15 m in the main. In the Pure Unbedded Limestones in the west of the GWB, there may be an epikarstic layer of around 1-2 m. Below this, the occurrence of dissolution bands and/ or jointing and faulting controls the inflow intervals. Most groundwater flow occurs in the top approximately 15-20 m, although deeper groundwater flow can occur along faults and fractures.
Overlying Strata	Lithologies	<i>[Information to be added at a later date]</i>
	Thickness	The groundwater body is large and with varied topography, hence the subsoil thickness varies very widely. From the quite limited available data, depth to bedrock appears to be greatest in the southeastern part of the GWB. Here, in the area roughly between Bridgetown and Lough Derg, particularly along the Black and Ardclony River valleys, subsoil thickness typically varies between 15 and 35 m and can reach 49 m. There are gravel aquifers delineated on the opposite side of Lough Derg and an infiltration gallery at Killaloe WS just to the north, so these may be gravel deposits. In the SW of the GWB, limited data indicate subsoil thicknesses of 3 to 8 m. There is some outcropping rock in this area also. In the uplands just south of Scarriff (just south of the impure limestone band bisecting the GWB), DTB can range from 1-17 m, with most data in the range 1-5 m. There are widely-scattered outcrops in this area. Over most of the rest of the GWB, subsoils are shallower, generally in the range 2-15 m, although occasional deeper subsoils (31 m, 46 m) are encountered near the River Graney downstream of Lough Graney. Outcropping rock is scattered across the northern zone of the GWB, but is concentrated in the upland areas. In the west of the GWB, between the Rivers Ayle and Cloughaun, subsoil thickness generally ranges between 10-35 m.
	% area aquifer near surface	<i>[Information to be added at a later date]</i>
	Vulnerability	<i>[Information to be added at a later date]</i>
Recharge	Main recharge mechanisms	Diffuse recharge will occur via rainfall percolating through the subsoil. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope. In general, due to the generally low permeability of the aquifers within this GWB, a proportion of the recharge will discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer. Where water tables are high, recharge may be rejected.
	Est. recharge rates	<i>[Information to be added at a later date]</i>
Discharge	Important springs and high yielding wells (m^3/d)	There are no Excellent ($>400 \text{ m}^3/\text{d}$) yielding boreholes known in this GWB. There is one 'Good' ($100 \text{ m}^3/\text{d} < \text{yield} < 400 \text{ m}^3/\text{d}$) yielding well in the same rock unit group aquifers just in the adjacent Tynagh GWB (at Scarriff, $180 \text{ m}^3/\text{d}$). The remainder of the known boreholes have Moderate and Poor yields ($< 100 \text{ m}^3/\text{d}$). Springs have Low yields ($< 430 \text{ m}^3/\text{d}$) and some go dry in summer. At Killaloe WS, abstraction is $525 \text{ m}^3/\text{d}$, but this is an infiltration gallery in a sand and gravel deposit adjacent to a river; water is not abstracted from bedrock. The S&G deposit is not classified as a Gravel aquifer.
	Main discharge mechanisms	Groundwater discharges to the gaining streams and rivers crossing the GWB. The upper impure limestone, pure bedded limestone and lower impure limestone aquifers have low storage capacity and cannot sustain high summer baseflows to the rivers. Groundwater also discharges at the edges of bogs and within bogs as 'flushes' and quaking areas. Springs within the GWB tend to have low to intermediate yields, and may dry up in summer.

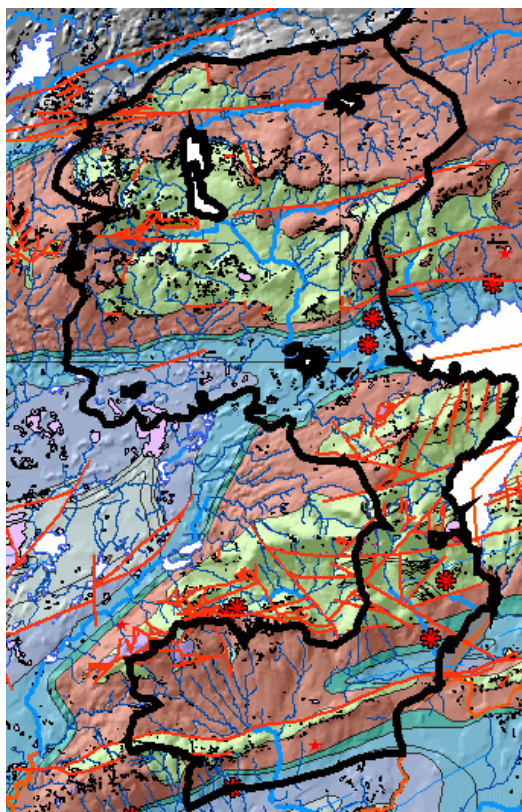
Hydrochemical Signature	<p>There are limited hydrochemical data available for this GWB. From available data and by analogy with the similar Nenagh and Slieve Felim GWBs, it is likely that groundwaters from all aquifers within this groundwater body have a calcium-bicarbonate signature. Hardness, alkalinity and electrical conductivities will vary between the aquifers, however. Groundwaters from the Silurian strata are likely to range from slightly hard to hard (90–360 mg/l CaCO₃), with alkalinities ranging from 60 to 270 mg/l (as CaCO₃) and electrical conductivities from 260–600 µS/cm. pHs will be neutral. The majority of samples are at the upper end of the range. At springs, or other systems where throughput is rapid, groundwaters have limited dissolved solids. In the Old Red Sandstone aquifers, groundwaters are moderately hard (145-235 mg/l as CaCO₃) with moderate alkalinities (140-225 mg/l as CaCO₃) and electrical conductivities (310-440 µS/cm), and neutral pHs. The groundwater is characterised by relatively low calcium and magnesium concentrations, but elevated iron and magnesium. It has been demonstrated that at low pumping rates water does not reside long enough in the well for oxidation to occur, thereby resulting in elevated Fe and Mn in small domestic supplies (Applin <i>et al</i>, 1989). In the Dinantian (early) Sandstones, Limestones and Shales, the Lower Impure Limestones and the Pure Unbedded Limestones, groundwaters will be hard to very hard (typically ranging between 380–450 mg/l), with high electrical conductivities (650–800 µS/cm) often observed. Alkalinity is also high, but less than hardness (250-370 mg/l as CaCO₃). Within the Impure and mixed Limestones, iron and manganese concentrations frequently fluctuate between zero and more than the EU Drinking Water Directive maximum admissible concentrations (MACs). Hydrogen sulphide can often reach unacceptable levels. These components come from the muddy parts of these rock units and reflect both the characteristics of the rock-forming materials and the relatively slow speed of groundwater movement through the fractures in the rock allowing low dissolved oxygen conditions to develop.</p>
Groundwater Flow Paths	<p>These rocks are devoid of intergranular permeability; groundwater flow occurs in fractures and faults. In the main, the rocks are dependent on fracturing and fissuring to enhance their permeability. Most of the flow originates in the shallow zone near the top of the aquifer, although faulting in certain areas can act as both high transmissivity zones that concentrate groundwater flow and as groundwater flow barriers. The pure limestones may have had their transmissivity enhanced further by dissolution of calcium carbonate along fracture and bedding planes. Zones of high permeability can be encountered near fault zones and in areas of intensive fracturing.</p> <p>Permeabilities in the upper few metres are often high although they decrease rapidly with depth. In general, groundwater flow is concentrated in the upper 15 m of the aquifer. Evidence of the relatively low permeabilities is provided by the drainage density and flashy runoff response to rainfall in areas underlain by Silurian and Devonian rocks. Areas underlain by Pure Unbedded Limestones are generally well-drained. This is due to the probable presence of an epikarstic layer.</p> <p>Water levels in the Old Red Sandstones and the Silurian rocks are usually less than 15 m below surface, with modal values of about 7.5 mbgl. However, deeper water levels of up to 37 mbgl are observed, indicating that there may be areas of the aquifers that are unconnected hydraulically to the rest of the aquifer, since local topography does not account for all of this variation. In the low-lying areas underlain by Impure Limestones and Pure Unbedded Limestones, groundwater levels are typically between 2 and 8 mbgl, although deeper groundwater levels (12-24 mbgl) are observed near to the surface water catchment divide. Next to the rivers, water levels will be closer to ground level. In Devonian Sandstones in the south of the GWB the water table is very shallow and seasonal water level variations recorded by the EPA are less than 1 m. The small variation and water table elevation indicate proximity to a discharge zone, which is probably caused by a combination of topography and the nearby lower transmissivity Dinantian (early) Sandstones, Limestones and Shales.</p> <p>Groundwater flow paths are generally short, with groundwater discharging to springs, or to the streams and rivers that traverse the aquifer. Flow directions are expected to approximately follow the local surface water catchments and to be determined by local topographic variations. There is no regional groundwater flow. Generally speaking, these rocks are unconfined, except where the aquifers are overlain by raised bogs, which have very low permeability clayey bases.</p>
Groundwater & Surface water interactions	<p>Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. The streams crossing the aquifer are gaining although, since aquifer storage is low, significant summer baseflows to the rivers cannot be sustained in most areas. Lough Derg, as well as receiving surface water input, will be sustained by groundwater flow, some of it originating from this GWB. Other Loughs in the GWB, such as Lough O'Grady (NHA001019) and Lough Graney will receive groundwater. At most of the raised bogs designated as NHAs (such as Loughatorick and Pollagoona Bogs, amongst others), groundwater upwells at the edges of the bogs, and flushes the areas with mineral rich water, or contain quaking zones. The Lough Graney Woods (NHA001714) contains springs that specific vegetation depends on.</p>

Conceptual model	<ul style="list-style-type: none"> • The groundwater body is bounded to the west, north and northeast by surface water catchments, to the southeast by Lough Derg and the River Shannon, and to the south by the contact with the karstified limestones of the Ardnacrusha GWB. The terrain ranges between mountainous in areas underlain by Silurian and Devonian rocks to flat-lying or gently undulating in areas underlain by the impure and pure limestones. • The groundwater body is comprised of generally low transmissivity and storativity rocks. The older rock units (i.e., Silurian and Devonian) are likely to have the lowest transmissivities, whereas the Pure Unbedded and Lower Impure Limestones (i.e. younger rock units) will have better flow properties. Transmissivities are generally lower in the northern part of the GWB than in the south. Aquifer specific yield is low in all aquifers. However, where gravels, extensive alluvium or very sandy till overlies the bedrock aquifer (such as at Killaloe), this can contribute to the storage. • Flow occurs along fractures, joints and major faults. Faults within the rocks may act both as groundwater flow conduits and barriers. Within the pure limestones, transmissivity may have been enhanced further by dissolution of calcium carbonate along fracture and bedding planes. Flows in the aquifer are typically concentrated in a thin zone at the top of the rock. An epikarstic layer may exist at the top of the Pure Unbedded Limestones. • Recharge occurs particularly in the upland areas, and where rock outcrops, or subsoils are thin. Much of the potential recharge runs off in the upland areas. Where the water table is close to the surface in upland or lowland areas, potential recharge may be rejected. • Aquifers within the GWB are mainly unconfined. They are probably only confined where raised bogs with low permeability clayey bases overlie the aquifers. Depending upon the local topography, the water table can vary between a few metres up to >10 m below ground surface. Locally, groundwater flows to the surface water bodies and is determined by local topography; there is no regional flow system. Flow path lengths in the upland and lowland areas are short (30-300 m). The increased hydraulic gradient, due to the sloping topography in the upland areas, will allow groundwater to flow faster than if it were flowing through a similar rock type in low-lying land. • Groundwater discharges to springs and to the numerous streams and rivers crossing the aquifer, and to Lough Derg. • Due to the shallow groundwater flow in this aquifer the groundwater and surface waters are closely linked. There are several ecosystems in the GWB dependent on groundwater. Groundwater and surface water interactions require special attention where the terrestrial ecosystems within this GWB are dependant on a sustainable balance between the two.
Attachments	Groundwater hydrographs (Figure 1).
Instrumentation	Stream gauges: 25030, 25078, 25123, 25210, 25237, 25241, 25242, 25243, 25250, 25257, 25259. EPA Water Level Monitoring boreholes: Clonlara (CLA 067).
Information Sources	Applin, K. R. and N. Zhao (1989) The Kinetics of Fe(II) Oxidation and Well Screen Encrustation. <i>Ground Water</i> , Vol 27, No 2. Kelly, C. <i>Shinrone Public Supply-Groundwater Source Protection Zones</i> . Geological Survey of Ireland Report to Clare Co. Co., in preparation. Deakin, J. and Daly, D. (2000) <i>County Clare Groundwater Protection Scheme</i> . Geological Survey of Ireland Report to Clare Co. Co. (draft), 71 pp. Hunter Williams, N., Motherway, K. & Wright, G.R. (2002) <i>Templederry WS, Groundwater Source Protection Zones</i> . Geological Survey of Ireland, 18 pp. Aquifer chapters: Devonian Old Red Sandstones; Dinantian Lower Impure Limestones; Dinantian Pure Unbedded Limestones; Silurian Metasediments and Volcanics; Dinantian Pure Bedded Limestones.
Disclaimer	Note that all calculations and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

Figure 1: Groundwater hydrograph



NB: this monitoring point is in the Devonian Old Red Sandstones near to the boundary with the overlying Dinantian (early) Sandstones, Limestones and Shales.



Rock units in GWB

Rock unit name and code	Description	Rock unit group
Ballysteen Formation (BA)	Fossiliferous dark-grey muddy limestone	Dinantian Lower Impure Limestones
Ballynash Member (BAbn)	Wavy-bedded cherty limestone, thin shale	Dinantian Lower Impure Limestones
Visean Limestones (undifferentiated) (VIS)	Undifferentiated limestone	Dinantian Lower Impure Limestones
Waulsortian Limestones (WA)	Massive unbedded lime-mudstone	Dinantian Pure Unbedded Limestones
Lower Limestone Shale (LLS)	Sandstone, mudstone & thin limestone	Dinantian (early) Sandstones, Shales and Limestones
Ayle River Formation (AR)	Mudstone, siltstone, conglomerate	Devonian Old Red Sandstones
Old Red Sandstone (undifferentiated) (ORS)	Red conglomerate, sandstone, mudstone	Devonian Old Red Sandstones
Scalpnagown Formation (SG)	Conglomerate & sandstone, nodular	Devonian Old Red Sandstones
Maghera Cornstone Member (SGmc)	Massive nodular carbonate	Devonian Old Red Sandstones
Broadford Formation (BF)	Fine to conglomeratic graded greywacke	Silurian Metasediments and Volcanics
Cornagnoe Formation (CE)	Green, mottled siltstone & mudstone	Silurian Metasediments and Volcanics
Slieve Bernagh Formation & conglom & coarse greywa (cgSB)	Fine & some coarser greywacke	Silurian Metasediments and Volcanics
Cratloes Formation (CR)	Laminated siltstone & sandstone	Silurian Metasediments and Volcanics
Ballycar South Member (CRbs)	Fossiliferous conglomeratic sandstone	Silurian Metasediments and Volcanics
Glennagross Member (CRgc)	Conglomeratic sandstone	Silurian Metasediments and Volcanics
Derryfadda Formation (DF)	Greywackes, siltstone and mudstone	Silurian Metasediments and Volcanics
Greywacke sandstone (gw)		Silurian Metasediments and Volcanics
Broadford Formation & Greywacke sandstone (gwBF)	Fine to conglomeratic graded greywacke	Silurian Metasediments and Volcanics
Kilarena Formation (KA)	Greywacke, siltstone & shale	Silurian Metasediments and Volcanics
Slieve Bernagh Formation (SB)	Fine & some coarser greywacke	Silurian Metasediments and Volcanics
Ballymalone Formation (BO)	Black graptolitic shale & chert	Ordovician Metasediments
Purple grit (pg)		Ordovician Metasediments
Caher Hill Formation (CH)	Tuff, lavas and clastic sediments	Ordovician Volcanics