The Magnesian Limestone

The Magnesian Limestone is the traditional name which has been applied to a sequence of rocks above the Marl Slate. The name Magnesian Limestone has been discarded in recent formal geological publications. However, as no direct equivalent has been proposed, the name has been retained in this report in order to inform and complement its continued use in a host of biodiversity and other reports.

It is important to differentiate between the geological unit the Magnesian Limestone and the rock type 'magnesian limestone'. The Magnesian Limestone contains a variety of rock types, mainly limestones of different compositions including magnesian limestone and may contain distinctive species of fossils.

Whereas true limestones are rocks composed predominantly of the mineral calcite (CaCO3), many contain magnesium, most commonly as the mineral dolomite ($CaMg(CO_3)_2$). Limestones are named on the basis of their dolomite content thus:

limestone 0–10% dolomite

dolomitic limestone 10–50% dolomite

calcitic dolomite 50–90% dolomite

dolomite or dolostone 90–100% dolomite

It is important to appreciate that the term 'dolomite' is applied to both the mineral dolomite (CaMg(CO3)2), and a carbonate rock containing between 90 and 100% of this mineral.

Geological SSSIs

SSSI Name/GCR Name/Grid Reference

Crime Rigg And Sherburn Hill Quarries/Crime Rigg Quarry [NZ 344 416]

Durham Coast/Blackhalls Rocks [NZ 468 395]

Durham Coast Seaham Harbour [NZ 430 499]

Hawthorn/Hawthorn Quarry Quarry [NZ 435 463]

Middridge/Middridge Quarry Quarry [NZ 252 252]

Raisby Hill Quarry/Raisby Hill [NZ 346 354]

Stony Cut, Cold Hesledon/Cold Heseldon [NZ 417 472]

Trimdon Limestone Quarry/Trimdon Grange Quarries [NZ 361 353]

Yoden Village/Yoden Village Quarry Quarry [NZ 436 417]

Permian rocks are also exposed within a number of areas scheduled as SSSIs, but not specifically designated for Permian rocks within the Geological Conservation Review.

Durham County geological sites

Bishop Middleham Quarry [NZ 3331 3332]

Dene Holme [NZ 454 404]

Old Quarrington Quarry [NZ 32 38]

Townfield Quarry, Easington Colliery [NZ 434 436]

Castle Eden Dene [NZ 4223 379]–[NZ 440 400]

Ferryhill Gap [NZ 30 34]–[NZ 30 32]

Hesleden Dene and [NZ 434 388] downstream continuation — [NZ 469 370]

Old Towns Quarry [NZ 257 256]

Raisby Railway Cutting [NZ 345 350]

Rough Furze Quarry [NZ 317 326]

Beacon Hill and Beacon Hill Rail Cutting [NZ 443 455]

Thrislington Quarry [NZ 310 330]

Chilton Quarry [NZ 300 314]

Middridge Railway Cutting [NZ 250 251]

The Magnesian Limestone is made up of the following formally-defined geological units:

The Rotten Marl

The Seaham Formation

The Seaham Residue and Fordon Evaporite Formation

The Roker Dolomite Formation (includes the Concretionary Limestone Member)

The Ford Formation

The Raisby Formation

The Raisby Formation (formerly known as the Lower Magnesian Limestone)

This lowest division of the Magnesian Limestone includes rocks which range in composition from yellow or cream dolomites to almost pure, grey limestones, though the latter are rare. Three main lithological units, distinguished by colour, bedding thickness, texture and compositional variations can be recognised in many areas. The middle unit is the one most commonly seen; it is a sparingly fossiliferous hard rock with a characteristic mottling rarely found in other parts of the Magnesian Limestone. Lower units of the Raisby Formation are more regularly bedded and, on the whole, slightly coarser grained. Laminated argillaceous layers, commonly of brown clay, are present especially near the base of the sequence. Fossils are rare in the upper unit, but are locally common in the lowest unit. Calcite-lined cavities are characteristic of many sections and may represent the replacement of original evaporite minerals.

The formation has only a narrow surface outcrop, which is mainly drift free or only thinly drift-covered, commonly along an escarpment 30 to 60 metres high, but it extends beneath younger strata to the eastern edge of the county. The Raisby

Formation is a major source of aggregate.

The Raisby Formation was deposited on a shelf sloping gently eastwards into the Zechstein Basin. During deposition of the limestone this slope was the cause of instability and at times there were minor submarine “avalanches" or slumping of partly lithified sediment which moved downslope. The chaotic and often contorted rock structures produced by such slumping can be seen locally in the rocks of the Raisby Formation.

The type Section is in Coxhoe Quarry (formerly known as Raisby Quarry).

At Thickley Quarry the lowest beds of the formation, which comprise thick-bedded dolomitic limestones, are overlain by fossiliferous limestone texturally similar to those at Raisby Hill Quarry. At Raisby this unit is 30 metres thick; at Thickley it is only 1 metre thick.

The Ford Formation (formerly known as the Middle Magnesian Limestone)

The Ford Formations displays a varied sequence of dolomites deposited in three distinct environments: shelf-edge reef that separates a broad belt of back-reef and lagoonal beds to the west from a belt of fore-reef talus aprons and off-reef beds to the east.

The barrier reef of the Ford Formation is perhaps the best known feature of the Durham limestones of reef-facies crop out in a sinuous Upper Permian. Most of the reef consists of massive unstratified rock which in places is at least 100m thick. It is composed predominantly of the skeletons of marine animals known as bryozoans along with many shells, some sea urchins and rare corals. Dolomites and dolomitic belt extending south-south-eastwards from Down Hill near Sunderland towards West Hartlepool. This has locally been much more resistant to erosion than adjacent bedded rocks and in places forms distinct topographic features such as Beacon Hill near Easington.

It is not always easy to distinguish where the Raisby Formation ends and the Ford Formation starts.

Rocks of the lagoonal type occupy most of the Ford Formation outcrop. They consist of a thick series of granular, oolitic and pisolitic carbonate rocks which are almost universally dolomitized. In most of these rocks the dolomite has recrystallised into platy crystals up to 5 mm across which give rise to a texture referred to as 'felted' and which is virtually confined to these lagoonal beds within the Ford Formation.

Not all of the rock types of the formation are well exposed within Durham. Many are better displayed immediately to the north in the Sunderland area. However, a number of the classic reef exposures to the north of the county have now been obscured. One of the largest exposures of late Permian reef-rocks in North- East England is at Hawthorn Quarry. An unusual algal-laminated dolomite, known as the Hesleden Dene Stromatolite Biostrome, overlies the top of the reef at Hawthorn Quarry. It has a boulder conglomerate at its base. The biostrome is named from its occurrence further south in Hesleden Dene. It is also very well exposed at Blackhalls Rocks.

The Roker Formation (Hartlepool and Roker Dolomites)

The Roker Formation consists of thin-bedded and flaggy cream finely granular dolomite and oolitic dolomite. It includes the well-known 'Concretionary Limestone', now formally defined as the Concretionary Limestone Member of the Roker Formation.

The Concretionary Limestone is by far the most varied carbonate unit of the English Zechstein sequence. Its best known feature is a range of calcite concretions which are spectacularly developed in the Sunderland area in the 'Cannonball Rock'. In coastal exposures in Durham the Concretionary Limestone falls into a lower group of beds containing abundant concretionary structures and an upper group in which such structures are generally absent. The lower beds are often so laterally variable that exact correlation of adjacent sections is difficult and the concretions lack the wide range of forms found in the Sunderland area. The formation is composed mainly of thinly bedded granular dolomites of silt- to fine-sand grade, but the rock is locally recrystallised and in some places contains many concretions. When freshly broken these

rocks usually smell strongly of oil. In all onshore areas the Concretionary Limestone has foundered and lower beds have suffered varying degrees of collapse brecciation due to the solution of the underlying Hartlepool Anhydrite.

The widespread 'Flexible Limestone', commonly present slightly below the middle of the member, is a thin laminated unit which locally can split into flexible paper-thin sheets. It yielded fish remains in the Sunderland district, but none is known from County Durham. Plant debris is locally common.

The Concretionary Limestone Formation is exposed in coastal cliffs north of Seaham and intermittently in coastal exposures around Easington Colliery, and from Horden to Blackhall Rocks. Inland it is seen in Castle Eden and Nesbitt denes. Small calcareous concretions occur in the cliffs north of Loom [NZ 444 443] and south of Blue House Gill thin-bedded dolomitic limestones contain abundant concretionary structures [NZ 4682 3941] and in the upper part of the cliffs at Limekiln Gill [NZ 477 382] some bedding planes contain the worm Tubulites.

In those parts of Durham where the Concretionary Limestone is not developed, the Roker Formation consists of beds of dolomite and oolitic dolomite. It is exposed in the coastal cliff section near Cross Gill, Blackhalls Rocks [NZ 4756 3821], where the topmost part consists of oolitic dolomite. Rocks of the Roker Formation also form a series of isolated outcrops between slipped masses of glacial deposits for about 410 metres on the north side of Dene Mouth [NZ 457 408]. Inland it is exposed on the south side of Castle Eden Burn with limited exposures in Nesbitt Dene and Hardwick Dene.

The Seaham Formation

Although highly variable, the Seaham Formation is the most uniform of the Late Permian carbonate units. It consists predominantly of thin-bedded limestone with some dolomite, but in places may resemble the Concretionary Limestone.

The formation carries a unique and distinctive diagnostic assemblage of algae and bivalves. Small tubular, stick-like remains of the probable algae Calcinema permiana are present in great abundance. The Seaham Formation is exposed mainly in coastal cliffs at Seaham, but is also patchily exposed inland in Seaham Dene. Its type exposure is in the sides of the dock at Seaham Harbour.

The Rotten Marl

The Rotten Marl is a dull dark red-brown silty mudstone, which in borehole cores contains scattered halite crystals and a network of veins of fibrous halite and gypsum. It occurs in situ only south of the county and offshore. It was exposed within the filling of a breccia pipe, or fissure filling, at the top of the north wall in Seaham Dock, but has now been largely obscured.

Influence on the landscape

The Permian rocks of East Durham form a low upland plateau of Magnesian Limestone sloping gently eastwards to the sea and southwards to the Tees plain, and defined in the west by a prominent escarpment. The soft Permian rocks that underlie the plateau are locally well exposed on the escarpment and at the coast, but elsewhere are covered by a mantle of glacial drift. The topography of the plateau is gently undulating and is deeply incised in the east by coastal denes. The coastline is one of clay-crested limestone cliffs, giving way in the south to low dunes, with a foreshore of sandy beaches and rock outcrops heavily disfigured in the north by tipping of coal wastes.

The escarpment and parts of the plateau have also been affected by the quarrying of limestone. Large active and disused quarries occupy prominent sites on the escarpment. A number of older quarries that have naturally re-vegetated are managed as nature reserves.

The landscape is generally open and broad in scale although the plateau terrain rarely affords long distance views. From the higher ground of the escarpment there are panoramic views across the Wear lowlands to the Pennine fringes beyond, and south across the Tees plain to the Cleveland Hills. The landscape of the plateau has been heavily

influenced by urban and industrial development and its scattered mining towns and villages and busy roads locally give it a semi-rural or urban fringe character.

The Magnesian Limestone, though widely covered by drift, has exerted a profound effect on both the natural and social history of eastern Durham. Exploitation of the huge coal reserves concealed beneath the Magnesian Limestone began early in the 19th century. Coincident with this mining activity came the development of numerous colliery settlements.

Influence on biodiversity

The grasslands that have developed on soils derived from Magnesian Limestone form an important variant of calcareous grassland, which is unique to North East England, with the majority of the remaining resource, approximately 225 hectares, occurring in County Durham. The most significant sites include the National Nature Reserves at Thrislington and Cassop Vale where primary Magnesian Limestone grassland still occurs. Other statutory sites display secondary grassland where species of interest have colonised the rudimentary soils occurring within abandoned quarries.

Thrislington, in particular, is noted for its rich assemblage of interesting plant species including several southern species, such as perennial flax, growing near the northern limit of their distribution together with species of northern distribution such as blue moor grass and mountain everlasting. The dark red helleborine and the glow worm are both Biodiversity Action Plan species which also occur at this site.

The shallow calcareous soils of the steeper escarpment slopes generally have a pastoral aspect and contain areas of well-established Magnesian Limestone flora. Ash woodland or mixed broadleaved woodland with ash often dominant is developed in some of the coastal denes. Castle Eden Dene represents one of the finest examples of yew woodland in Europe.

Quarries in the Magnesian Limestone have been worked according to demand, one opening when another closes, or sometimes remaining idle for long periods. In these circumstances they have provided suitable habitats, free from competition, for colonisation by the plant species present in the unique semi-natural grasslands nearby. It is possible that the quarries which are active today will provide alternative sites in the future.

Economic use

The Magnesian Limestone has provided, and continues to provide, a wide variety of economic products.

Building Stone

It is likely that prior to 1800 the rocks of the Magnesian Limestone were used mainly for building purposes, and many of the early settlements along the Permian escarpment were built of dolomitic limestone and dolomite worked in numerous small and a few large quarries. Most of these were opened in the evenly bedded Raisby Formation which offered the most suitable building material. With the exception of the reef-rock, which has been used on a small scale in buildings at Hawthorn, Easington, Peterlee and Hesleden, the dolomite of the Ford Formation is usually too soft and variable for building purposes.

Agricultural lime

There is historical evidence that the Magnesian Limestone was being quarried in earnest in Durham for lime burning in the mid to late 18th century. With the increasing use of lime for agricultural purposes in the early part of the 19th century a number of quarries in the Raisby Formation and some new ones, including the large Tuthill Quarry in the Ford Formation near Haswell, supplied burnt or ground lime. High calcium 'magnesian limestone' was burnt at Coxhoe and Ferryhill Station for many years and probably also at Hawthorn, Running Waters and Bishop Middleham. The introduction during the Second World War of the Agricultural Lime Scheme encouraged much greater use of lime in agriculture and there has been a trend towards the use of ground magnesian limestone, where readily available, instead of the more traditional burnt or ground limestone.

Flux

The development of iron making in North-East England has led to a demand for high calcium Magnesian Limestone to supplement Carboniferous limestone for us as a flux in blast furnaces. Extraction for this purpose started around 1850 and continued in considerable volume until about 1920 when the iron makers began to substitute high magnesian limestone for high calcium limestone in their furnaces. Among the quarries worked were Raisby Hill, Wingate, Tuthill, Bishop Middleham and Hawthorn. The use of magnesian limestone as a flux continues to this day.

Dolomite refractory

When the Bessemer & Siemens system for the bulk production of steel was developed in 1850/60 local iron ores could not be used. These ores contained a relatively high proportion of phosphorus and sulphur which attacked the steel furnace-lining when incorporated in the slag formed in the melting process. This problem was resolved with the development of a refractory lining capable of withstanding chemical attack from the basic steel slag. Although lime was chemically suitable it lacked physical stability and it was discovered that a certain type of magnesian limestone (normally a true dolomite) when dead burnt, provided excellent refractory properties both chemically and physically. The production of "basic bricks" at Leasingthorne using Magnesian Limestone from Westerton Quarry, Bishop Auckland, was recorded in 1884. Commercial kilns, "cupolas", for the production of dead burnt Magnesian Limestone were built at Raisby. The product known as "basic" was later given the commercial name Doloma". Coxhoe and Joint Stocks Quarries saw the biggest development in the production of Doloma. By 1920 Doloma was being produced at Coxhoe, Raisby and Cornforth quarries.

Magnesia and Magnesite

In 1844 Magnesia (magnesium oxide, MgO), was produced by the Washington Chemical Co. under the leadership of H.G. Pattison, one of the greatest industrial chemists of his day. By 1870 his relations had patented the process of making basic magnesium carbonate or magnesite ($MgCO_3$) and magnesium oxide from dolomite using magnesian limestone from the Hylton Quarry at Sunderland. Magnesia has been produced in Darlington for pharmaceutical and insulation products since 1928. Magnesian limestone, mainly from Aycliffe quarries, was used until the 1970's when the process was changed to use calcined dolomite from Thrislington Quarry.

In 1937 the opening at Hartlepool by the Steetley Company of a plant to manufacture a magnesite product from dolomite and seawater marked an important development in the use of magnesian limestone. Known as the Palliser Works, the plant relied on regular and steadily increasing supplies of dolomite lime, 'Dolime' from Coxhoe Quarry. As recently as 2003, Dolime, for the plant was being supplied from Thrislington Quarry. Magnesia (magnesium oxide, or MgO) has exceptional properties of electrical resistance and heat conductivity which makes it the preferred insulation material used in the manufacture of domestic and industrial heating elements.

Construction

The construction industry has become the dominant market for magnesian limestone since the mid 1960's. Although not the most suitable aggregate for construction, magnesian limestone has been used very successfully for bulk fill and hardcore and, after careful selection, for roadstone, drainage systems and the coarse aggregate for concrete production. It has also been used for the surfacing of running tracks and, before the advent of Astroturf, the hard porous areas for football and hockey pitches. At Raisby the Magnesian Limestone of the Raisby Formation was used for the manufacture of Tarmacadam. The construction boom in the Tyne Tees area over the decade 1965–1975 saw the reopening of a number of old workings which had existing planning permission. Among the quarries reopened were Tuthill near Easington, Hawthorn Quarry, Haswell Moor Quarry, Hart Quarry, Bishop Middleham Quarry and Stonegrave Quarry at Aycliffe.

Lime for use in mortar has also been obtained from the Magnesian Limestone.

Future commercial interest

Continued working of Magnesian Limestone for its present uses can be expected.

Environmental issues

Widespread underground coal extraction has taken place beneath the Magnesian Limestone of much of the county. During active mining, surface subsidence, in part facilitated by the well-developed system of joints within the limestone, was a common phenomenon, often requiring remedial work to affected structures and land. Since the ending of underground mining, surface subsidence has continued in a number of locations previously affected by such instability. There is also evidence of instability in areas not previously known to have been so affected. Recent research indicates a close spatial relationship between such collapse features and faults which cut the limestone and underlying Coal Measures. Observed features are consistent with some form of renewed subsidence or reactivated fault movement, perhaps related to rising groundwater levels in the Coal Measures rocks. The presence of such areas of known or potential instability need to be taken into account in all aspects of land-use planning across the Magnesian Limestone outcrop. Particular attention needs to be directed towards the management of present and future land-fill sites and the siting of major structures and services. Further studies of these phenomena, and their potential environmental impact on the County are recommended, especially in the light of proposals to discontinue, or modify, pumping of groundwater in the coalfield.

Selected references

Hirst and Dunham, 1963; Hutton, 1831; Magraw, 1963; Pattison, 1986; Sedgwick, 1829; Smith, 1970, 1971, 1981, 1994, 1995; Smith and Francis, 1967; Smith et al. 1974; Smith et al. 1986.

Figures and photographs

(Figure 19) Schematic cross section through Permian rocks of County Durham.

(Photo 25) Thrislington Quarry, Ferryhill. Dolomitic limestone with cavities, characteristic of part of the Raisby Formation. DJD Lawrence, BGS, ©NERC, 2004.

(Photo 26) Hesleden Dene. Algal domes in Magnesian Limestone. BGS, ©NERC, 2004.

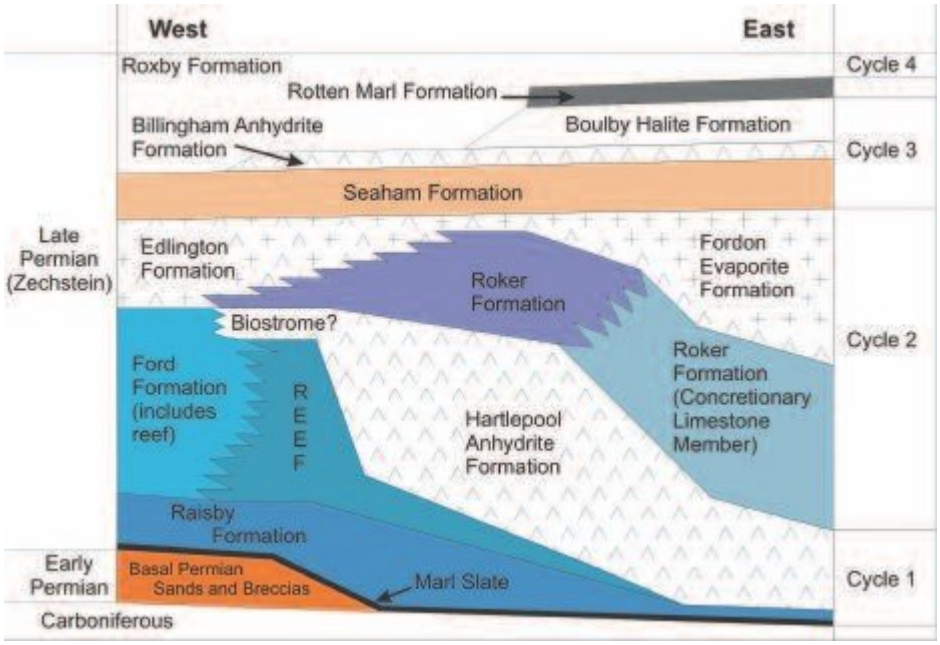
(Photo 27) Blackhall Rocks. Caves in Ford Formation. BGS, ©NERC, 2004.

(Photo 28) Quarrington. The escarpment of the Magnesian Limestone. DJD Lawrence, BGS, ©NERC, 2004.

(Photo 29) Heighington. Magnesian Limestone as a building stone: the quoins are Coal Measures sandstone. B Young, BGS, ©NERC, 2004.

(Photo 30) Coxhoe (Raisby) Quarry. Dolomitic limestone of the Raisby Formation. DJD Lawrence, BGS, ©NERC, 2004.

Full references



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