The limestones of Scotland v.1 — Chapter 4 Lithological characteristics

One of the most important geological features of a limestone is the information it usually gives regarding the life of the period during which it was formed; for most limestones are composed, in the first instance, of organic remains. Changes take place, however, during the processes of deposition, consolidation, and any subsequent metamorphism that the rock may undergo. These changes involve partial, or even complete, comminution, recrystallization and replacement of the original mineral constituents; so that much of the evidence left behind by the shell, coral and other life of the period is often obliterated. The final form in which the mass of limestone appears, and in which it becomes available for economic purposes, thus depends partly upon the original character of its constituents and partly upon the changes they have subsequently undergone.

a. Sedimentary limestone

As calcite is of all the more common rock-forming minerals that which most readily undergoes solution and recrystallization, limestones are usually well cemented; and if the body of the limestone is itself made up of only finely divided calcite mud a compact homogeneous rock is produced which rings under the hammer and breaks with a finely porcellanous to almost glassy fracture. The Burdiehouse Limestone in the Carboniferous and some of the calcite-mudstone beds in the Durness Limestone are examples of this type amongst those of organic origin. The cornstones of the Old Red Sandstone, the cementstones of the Lower Carboniferous, and the *Spirorbis* limestones of the Upper Carboniferous illustrate the same character amongst calcareous beds produced mainly by chemical precipitation.

Where the calcareous material consists mainly of finely comminuted shell-fragments and similar material, the general appearance of the limestone is rougher, and the fracture is more like that of earthenware than of porcelain. If well cemented however, the rock is little inferior in strength to a calcite-mudstone, and it is distinctly less brittle. Where the shell-fragments, or remains of other lime-secreting organisms such as bryozoa, algae, corals and crinoids are rather coarser, the rock is often very rough both on weathered and freshly broken surfaces, but the calcareous cement between the grains may give the rock a considerable degree of toughness.

Large crystals of calcite, such as those forming the stems and ossicles of crinoids, the infillings of cavities in the original deposit, and recrystallized shells, show a tendency to split along the crystallographic cleavage planes. They are thus often a source of weakness in the stone; although a rock composed entirely of crinoid ossicles or stems, with irregular orientation of the calcite grains, is sometimes quite tough in character. It breaks with an angular, sometimes almost hackly, fracture. This is the type commonly referred to as 'petit granit.'

Flaggy, sandy, argillaceous, tufaceous and other types of limestone are found in great variety, and the same bed may pass laterally through every stage in the transition from a pure calcite-mudstone or shell-aggregate to a sandy or argillaceous limestone, and thence to a sandstone or shale with only sufficient calcium carbonate in its composition to give incomplete cementation of the sandy or muddy aggregate. Such lateral changes usually take place very gradually.

b. Sedimentary dolomite

Most limestones contain a small amount of magnesium carbonate ($MgCO_3$) intimately intermixed with the calcium carbonate as an original constituent. This may or may not be indicated under the microscope by the presence of crystals of the mineral dolomite. Quantities of less than 5 per cent. $MgCO_3$ do not interfere with the common uses of the limestone except for chemical purposes, nor do they usually have any effect upon the lithological character of the rock.

In the vicinity of faults a certain amount of irregular replacement of limestone by dolomite is frequently found to have taken place, and this is usually attributed to the work of underground water circulation through the broken strata. This type of dolomitization is usually very irregular and patchy in character and is often vein-like in development. It is well shown in the Charlestown Main Limestone at the Charlestown quarries. Good examples of dolomite veins can be seen in the Burdiehouse Limestone at Newbigging mine, Burntisland.

The normal development of dolomite in the Carboniferous rocks of Scotland, however, is of quite a different character. In organically deposited calcareous sequences it occurs as definite beds, usually quite sharply distinct from any limestones with which it may be in contact by interbedding. Thus, the top post of the Bilston Burn Limestone in Midlothian is a dolomite. On the other hand, it is the bottom post of the Charlestown Main Limestone which is dolomite at Seafield and Cults in Fife. At Auchenheath the whole of the Calmy Limestone is dolomite.

On the freshly broken surface these dolomites are usually leaden grey to buff in colour, sometimes with the pearly lustre of the mineral dolomite clearly visible. The texture varies from smooth in the finer-grained varieties to distinctly crystalline in the coarser types. On the weathered surface they are usually distinctly (buff in colour in comparison with the grey tone of most limestones, and an ochreous appearance is not uncommon. The ochre-bed forming the highest post of the Bilston Burn Limestone in the Bilston Burn, Midlothian, was found on examination to be a partially decalcified ferro-dolomite. The majority of the cement-stones in the Calciferous Sandstone Series prove on analysis to be ferro-dolomite, showing calculated percentages of ferrous carbonate ranging up to over 17. It is noteworthy that in every case this ferrous iron appears to replace a portion of the magnesia in the dolomite molecule ($CaCO_3$, $MgCO_3$). These rocks are probably chemical precipitates and their grain is seldom coarse enough to show a crystalline appearance on the fractured surface.

The dolomites of the Durness Limestone occur as distinct beds, and in some parts of the sequence they alternate with beds of limestone, as is the case in the Carboniferous. In development, however, they are in some respects different from those of the Carboniferous. They range from fine-grained, compact, porcellanous types through finely crystalline varieties to rocks in which the texture is coarsely granular. Some of these types are almost characteristic of the groups of strata in which they occur. Thus the lowest beds, Group I, show dark-grey, fine-grained, but distinctly granular dolomites. In Group II the dominant type is a light-grey, finely crystalline dolomite, alternating with compact porcellanous varieties which were probably laid down originally as calcite-mudstones. In Group HI fine-grained, light-grey dolomites alternate with types fairly coarse to coarse in grain and showing small-scale patchiness in light and dark grey colours (leopard stone). Group IV shows grey, medium-grained dolomites, alternating with white and light-grey limestone in the upper half of the group. In Group V a fine-grained dolomitic mudstone type occurs with very fine bedding lines showing up clearly on the weathered surface like a fine ruling with some 20 to 30 lines to the inch. A rather similar type was found in Group II. Dark, medium to coarse-grained, leaden-grey dolomites are the most characteristic types in Group VI, though other varieties also occur.

c. Metamorphic limestone

Limestones amongst the less highly altered metamorphic rocks are often very little different in hand-specimen from those of the unaltered sedimentary type. The fine-grained varieties of the Loch Tay and other limestones in Argyll, for example, show a certain amount of recrystallization of the calcite; but in many places they do not appear to be any coarser in texture than the medium-grained limestones of the unaltered Carboniferous. The Lismore Limestone still retains much of its carbonaceous content, and the Islay Limestone still shows the original oolitic structure of some of its beds.

The more highly altered limestones of Perthshire, Inverness-shire, Aberdeenshire and Banffshire, on the other hand, are usually sufficiently coarsely crystalline to show the individual grains clearly in hand-specimen. The impurities, also, are often recrystallized into crystals of macroscopic dimensions, as in the tremolite, diopside, and other calc-silicate limestones in Aberdeenshire. The colour is seldom other than a medium to light shade of grey, though white and cream varieties also occur. A greenish tinge is in some places typical of those limestones with an appreciable amount of calc-silicate impurity.

In the, still more highly altered crystalline limestones of the Lewisian the texture ranges from fine-grained in some of the Loch Maree examples to coarsely saccharoidal in the case of the blue limestone of Glen Dessarry, Inverness-shire.

d. Metamorphic dolomite

Under the ordinary conditions of regional metamorphism a pure dolomite does not appear to undergo alteration, apart from a coarsening of the grain due to recrystallization. Dolomite has a much lower dissociation temperature and pressure than calcite, and where there are impurities present, siliceous, aluminous or ferruginous, the magnesia of the dolomite readily combines with them, forming tremolite, actinolite or hornblende according to the nature of the impurity. The composition of these minerals in most cases demands a greater proportionate amount of magnesia than of lime. Hence some of the lime in the dolomite molecule recrystallizes as calcite, so that metamorphism usually involves a certain amount of dedolomitization.

In higher grades of metamorphism, as in the impure magnesian limestones of the Lewisian, there is a further rearrangement of the constituents, giving diopside, forsterite and spinel. Examples are provided by the coarse-grained diopside-forsterite marble of Rodil in South Harris (Davidson, 1943) and the forsterite-spinel marble of Glenelg (Clough, 1910, p. 22).

e. Contact-altered limestone and dolomite

The effect of rise in temperature due to the proximity of intrusive magma, without the abnormal pressure and stress conditions of regional metamorphic action, has already been referred to (p. 19). In most Scottish occurrences there is not enough recrystalli7ation to cause much growth in the general grain-size, and the contact-altered limestones in consequence are usually finely granular in texture. Where impure but non-magnesian, as in the case of the Great Estuarine Series limestone at Strollamus in Skye, the result is a mosaic of granular calcite with wollastonite (calcium meta-silicate) and grossularite (lime garnet) produced by interaction of silica and alumina with the lime. The rock so formed is in this case white in hand-specimen and very tough. Where magnesia is present, as in the Cambrian dolomites, the result of heating is to break up the dolomite molecule. The magnesia thus set free crystallizes as periclase which, in the Scottish instances, is converted to brucite by hydration. The small amount of silica present combines with the requisite amount of magnesia to form forsterite and this is partly or wholly altered to serpentine by hydration. Thus are produced the brucite marbles of Skye and Sutherland. In many cases, however, there has been decomposition of only a portion of the dolomite, so that every stage in the transition from dolomite to non-dolomitic brucite-marble can be traced, depending upon the local incidence of temperature and pressure. The brucite-marbles are usually fine to medium in grain. They are white to grey in colour, with mottling in green, blue, and other tints when serpentine is present. They are usually little different from the unaltered granular dolomites in texture, but sometimes show distinct aggregates of brucite crystals in hand-specimen. On weathering they usually develop a white chalky skin owing to the conversion of the brucite into hydro-magnesite and the relative insolubility of this mineral in comparison with calcite.

f Calcite and dolomite veins

Calcite is a very common mineral in veins, fault-fissures and joints. As might be expected, calcite veins are particularly common in limestones, but they are also found in almost all types of rock. Owing to their light colour, calcite veins are generally conspicuous in a quarry face or natural outcrop. They are nearly always coarsely crystalline. In many instances the crystals have not developed faces, but only show the rhombohedral cleavage characteristic of calcite. Where there are free surfaces within the vein, however, well-formed crystals are frequently present including the sharp-pointed types spoken of as ' dog-tooth spar ' and the blunter types known as nail-head spar.'

Some calcite veins are exceedingly pure, or at most contain a small percentage of carbonate of iron. In many cases, however, other minerals are present, for example when the calcite is a gangue mineral in ore veins. The commonest non-metallic mineral associated with calcite in veins is quartz. As this mineral in some ways resembles calcite in crystallographic development it is sometimes mistaken for the latter, but can readily be distinguished by its much greater hardness and the absence of a good cleavage. Barytes is another mineral commonly found in calcite veins-; it can be distinguished from calcite by its platy crystals and by its much higher specific gravity. Although calcite veins are exceedingly common they seldom attain a sufficient thickness or a high enough degree of purity to be worth working separately from the main body of rock they cut.

An unusual type of impure dolomite crops out at intervals along the Highland Boundary Fault. It occurs in comparatively narrow bands between individual faults making up the fracture-zone, and has been formed through the alteration of serpentine and other ultra-basic and basic rocks rich in magnesia. The dolomite is massive in some localities, and brecciated in others. Although cream, grey or pink on the freshly broken surface it weathers with a characteristic bright orange-coloured crust. It is too impure to be used for most purposes for which dolomite is required but is of suitable composition to serve as a raw material for the manufacture of rock wool.

Specific Gravity of limestones and dolomites

The specific gravity of calcite is 2.71, and it is therefore to be expected that the specific gravity of limestones of a moderate or high degree of purity will approximate to this figure. A reduction, due to porosity, should perhaps be taken into account, but as most Scottish limestones are highly compact rocks, this effect is very slight. The great majority of Scottish limestones analysed (excluding dolomites) have specific gravities falling between 2.65 (165.6 lbs. per cubic ft.) and 2.75 (171.9 lbs. per cubic ft.) with an average of 2.70 (168.8 lbs. per cubic ft.). Consideration of the figures shows that it is not possible to draw any distinction, on grounds of specific gravity alone, between metamorphic and non-metamorphic limestone (apart from a special case noted below), or between limestones belonging to different formations.

Variations above or below the average are, of course, mainly due to the presence of constituents other than calcite. One of the commonest is quartz which, with a specific gravity of 2.65, tends to bring the specific gravity of the limestone somewhat below 2.70. A constituent that has a much more marked effect in this direction is carbon. The latter is plentiful in the Burdiehouse Limestone of the Lothians, most of the analysed samples of which have a specific gravity of under 2.67 or, in a few cases, even under 2.60.

Other constituents, of which the most important are compounds of magnesium and iron, tend to bring the specific gravity above the average. As these are often present along with quartz, there is frequently a counterbalancing effect; consequently highly impure limestones may have a specific gravity approximating to that of calcite. An interesting difference emerges at this point between sedimentary and some metamorphic limestones. While the specific gravity of the former, as just explained, is often unaffected by an increase in impurities, the density of the latter tends to rise due to the formation of calc-silicate minerals which have a comparatively high specific gravity.

Apart from calc-silicate-bearing limestones, almost the only calcareous rocks with specific gravities of over 2.75 are the dolomites and ferro-dolomites. Corresponding to the rare occurrence of limestone types with percentages of magnesium carbonate between 16 and 41 (*see* p. 31) there is a scarcity of limestones with specific gravities between 2.75 and 2.82. Of the comparatively few limestones which do have specific gravities falling within these limits, practically all are impure ferro-dolomites, the density of which has been reduced by the presence of abundant alumina and silica.

The specific gravity of pure dolomite ($CaCO_3$ 54.35 per cent., $MgCO_3$ 45.65 per cent.) is 2.87 (179.4 lbs. per cubic ft.). Nearly all iron-free dolomites have a specific gravity slightly lower than this figure owing to the presence of a small amount of calcite, and, in most cases, also of quartz. An average figure for Scottish dolomites is 2.85 (178.1 lbs. per cubic ft.).

Almost the only calcareous rocks with a specific gravity of over 2.87 are the Carboniferous ferro-dolomites which have specific gravities ranging up to 2.90 (181.2 lbs. per cubic ft.) or even more.

In the Durness Limestone of the North-West Highlands, where dolomites and limestones are found in close association, the specific gravity can be used as a quick method of indicating, within limits, the character of the calcareous rocks. This is referred to in greater detail in the description of the Sutherland limestones (p. 184).

Where dolomite has been altered by thermal-metamorphic action the specific gravity is lowered owing to the conversion of the magnesian portion of the dolomite molecule into brucite, which has a specific gravity of between 2.3 and 2.4. A rock composed wholly of calcite and brucite in equimolecular proportions has a specific gravity of approximately 2.57 (Kennedy, 1941, p. 2), and thus contact-altered dolomite may have a range of specific gravity from 2.85 to 2.57, depending on the degree of dedolomitization. Hence a partially altered dolomite may have the same specific gravity as a pure limestone. Further complications appear if impurities are present; and so, as pointed out by Kennedy, identifications based on specific gravity in such cases must be confirmed by other means, as by Lemberg's test for brucite. The Skye occurrences are an instance in point.