
Gargunnock Burn, Stirling

[NS 709 930]–[NS 707 933]

Introduction

Situated 9 km west of Stirling, the Gargunnock Burn [NS 707 930]–[NS 707 933] runs down the north-facing scarp of the Gargunnock Hills, which are the north-western extension of the Campsie Fells. A particularly fine stream section here reveals excellent outcrops of the Inverclyde Group (Tournaisian) lying between Upper Old Red Sandstone (Stratheden Group) below and the Clyde Plateau Volcanic Formation (Strathclyde Group) above. The section is critical in monitoring the subtle environment changes associated with earliest marine influences of early Tournaisian (Lower Carboniferous) age in the Gargunnock area. Read (in Francis *et al.*, 1970) has provided a meticulous account of the section, and detailed sedimentological descriptions and interpretations have been supplied by Belt *et al.* (1967) and Read and Johnson (1967).

Description

Within the Inverclyde Group at the Gargunnock Burn GCR site three formations are recognized. These are, in upward sequence, the Kinnesswood Formation, the Ballagan Formation and the Clyde Sandstone Formation. Representative sections of the Kinnesswood Formation and Ballagan Formation at this site are illustrated in (Figure 2.24). The Kinnesswood Formation, formerly referred to as the 'Cornstone Beds' (Francis *et al.*, 1970), is truncated at its base by a minor fault, but the loss of section is probably small and the formation here is 100 m thick (Francis *et al.*, 1970). The unit is largely composed of sandstones with subordinate siltstones and mudrocks. These are arranged in small-scale fining-upward cycles of sandstone passing up into, or overlain by, finer-grained rocks (Read and Johnson, 1967; Francis *et al.*, 1970). The sandstones are usually 3–7 m thick and vary from white to red or reddish-purple in colour. They typically show planar or trough cross-bedding and cut down into and rest disconformably on the rocks of the previous cycle. The basal parts of sandstone beds are often conglomeratic and contain calcrete clasts, breccias and scattered pebbles of quartz or quartzite. The siltstones and mudrocks are normally red in colour but may show mottling with green and buff colorations. These parts of the cycles are usually less than 2 m thick but have been truncated and in some cases entirely cut out by erosion at the base of the next cycle. The most distinctive feature of the Kinnesswood Formation is the presence of irregular layers and nodules of calcrete (see (Figure 2.24)). These are concretionary carbonates, which at Gargunnock are dolomitic, and occur in the upper part of cycles both in the mud-rocks and in the sandstones. In some instances corroded grains of quartz can be seen floating in the carbonate. The reworking of brecciated calcrete fragments at the base of cycles shows their penecontemporaneous origin.

The junction between the Kinnesswood Formation and the Ballagan Formation is not exposed in the Gargunnock Burn but lies within a 3 m gap in the exposures. A total of 50 m of Ballagan Formation are present in the section but the upper beds of the formation have been cut out by a strike fault which has resulted in the lower beds being faulted against sandstones of the overlying Clyde Sandstone Formation.

The Ballagan Formation is finer in character than the Kinnesswood Formation and is composed of cementstone bands and nodules, interbedded with mudrocks and sporadic fine sandstones (see (Figure 2.24)). The mudrocks, which are the dominant lithology, occur in beds up to 2 m thick and usually vary in colour from green to grey although some are red or brown in colour. They may be fissile or massive and are often silty or sandy in character. Occasionally they may pass into, or be interlaminated with, fine sandstones in beds up to 1 m thick. Although some of the cementstone nodules may be of secondary (diagenetic) origin, most of the nodules and the cementstone layers are primary dolomicrites. The cementstone layers are usually thin and the maximum thickness at Gargunnock is about 0.4 m. Boundaries with the adjacent mudrocks may be sharp or gradational and some bands show traces of internal lamination or brecciation. One stratified cementstone in the middle of the section has shrinkage cracks on its upper surface. Fish remains and obscure thin-shelled spheroidal and vermiform bodies have also been recorded from this bed (Francis *et al.*, 1970).

The Clyde Sandstone Formation, formerly known locally as the 'Downie's Loup Sandstones' (Francis *et al.*, 1970), is seen in outcrops south of and upstream from, the fault that truncates the Ballagan Formation. The sequence is about 70 m thick, but only about 20 m are exposed. Exposures are most complete towards the base of the sequence and are poor above the Downie's Loup waterfall, which is formed by a 7 m-thick intrusive sill. The sequence is dominated by white or greenish sandstones, which vary in grain size from fine-grained to conglomeratic. Limestone clasts are abundant in the coarser beds, but vein quartz, sandstone and mudclasts have also been recorded (Francis *et al.*, 1970). One of the sandstones contains a mudrock band with calcrete nodules. Mudstone alternations also occur in the lowest sandstone exposed. Reddish mudstones also occur at the top of the sequence and the highest of these (3 m), which is overlain by the lowest lava of the Clyde Plateau Volcanic Formation, contains decomposed volcanic material. The junction between the mudstone and the lava is irregular.

Interpretation

The three formations of the Inverclyde Group at Gargunnoch Burn show stratigraphically and palaeoenvironmentally significant changes in facies. The cyclical sequences of the Kinnesswood Formation were interpreted as fluvial deposits by Read and Johnson (1967) and the product of high-sinuosity channels developed on a gently sloping floodplain. Cross-bedded units reveal a wide range of current directions, but the predominant flow direction is from the north or north-west (Read and Johnson, 1967). The finer mudrocks in the cycles represent overbank deposits of the flood-plain. The calcretes have been compared by Read (in Francis *et al.*, 1970) with modern caliche or kankar-type soils and thus indicate an arid or semi-arid climate with a seasonal rainfall. The unusual, dolomitic character of the calcretes may have resulted from secondary replacement of calcite by magnesium-rich pore fluids linked to the deposition of the Ballagan Formation (Francis *et al.*, 1970; Hall *et al.*, 1998).

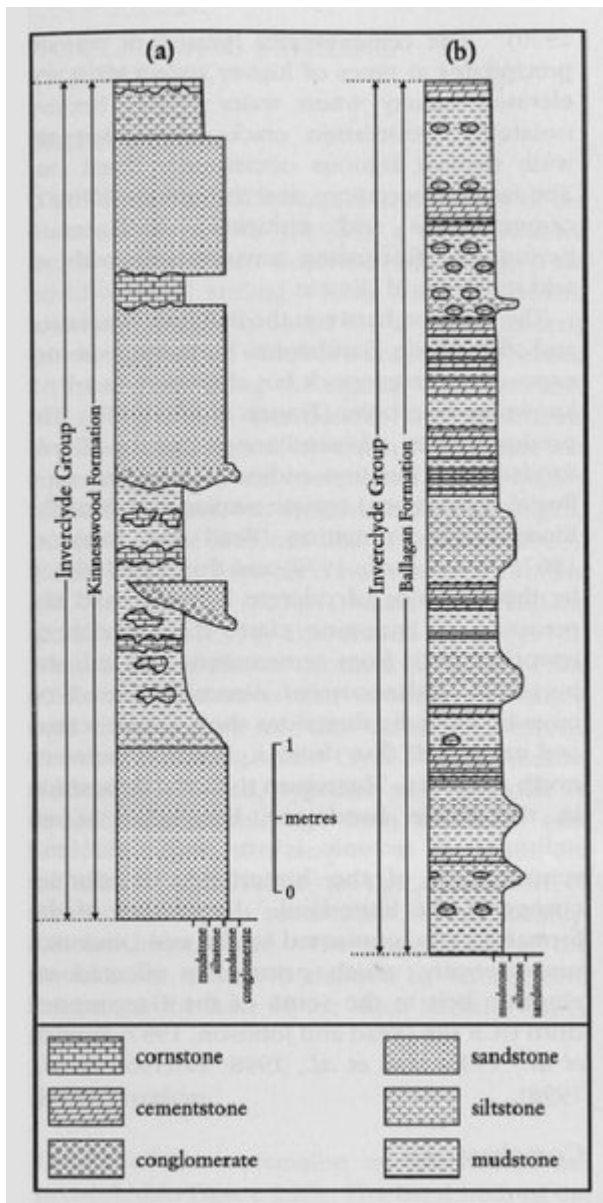
The finer-grained strata of the Ballagan Formation are interpreted as having been deposited in a wide protected coastal-flat environment (Belt *et al.*, 1967; Francis *et al.*, 1970). The cementstones formed as primary precipitates at times of higher evaporation and elevated salinity when water bodies became isolated. Desiccation cracks show that the wide shallow lagoons occasionally dried out. The facies associations and the interbedding of cementstones and mudrocks indicates a periodically fluctuating environment with an arid to semi-arid climate.

The junction between the Ballagan Formation and the Clyde Sandstone Formation is not exposed at Gargunnoch but elsewhere nearby is known to be erosive (Francis *et al.*, 1970). The predominance of sandstones in the Clyde Sandstone Formation indicates a return to a fluvial depositional regime similar to that of the Kinnesswood Formation (Read and Johnson, 1967; Francis *et al.*, 1970) and this is underlined by the presence of calcrete horizons and the presence of limestone clasts that have been reworked both from cementstone and calcrete horizons. Palaeocurrent directions based on cross-bedding dip directions show a wide scatter and an overall flow from a direction between north and west. The return to fluvial deposition in the Clyde Sandstone Formation is an indication of tectonic activity with uplift and rejuvenation of the hinterland, or climate change in the hinterland. Deposition of the formation was terminated by the mid-Dinantian unconformity, which principally affected an elongate belt to the south of the Gargunnoch Burn GCR site (Read and Johnson, 1967; Forsyth *et al.*, 1996; Hall *et al.*, 1998; Paterson *et al.*, 1998).

Conclusions

The Gargunnoch Burn GCR site is the best exposure of the Inverclyde Group on the northern margin of the Lower Carboniferous outcrop within the Midland Valley of Scotland and to the north of the area principally affected by the mid-Dinantian (late Tournaisian) unconformity between the Inverclyde Group and Strathclyde Group. Significant sedimentological studies have revealed in detail the palaeoenvironmental changes associated with the important transitions from deposition on an arid fluvial flood-plain (Kinnesswood Formation) to deposition in hypersaline lagoons on a marginal marine coastal plain (Ballagan Formation) and then, following rejuvenation, a reversion to fluvial deposition (Clyde Sandstone Formation).

[References](#)



(Figure 2.24) Representative sections of (a) the Kinnesswood Formation and (b) the Ballagan Formation of the Inverclyde Group at the Gargunnock Burn GCR site. Based on information in Belt et al. (1967) and Francis et al. (1970).