Depositional regime, Skiddaw and Manx groups, early Ordovician, Northern England

Introduction

Slump folds in the Buttermere Formation, Skiddaw Group, at Goat Crag, Buttermere, Cumbria [NY 1888 1629] (P005042.)

In the Isle of Man and towards the bottom of the Manx Group succession, the Peel volcanic assemblage is associated with turbidite strata of late Tremadoc to early Arenig age. Its significance in the context of sedimentary basin development is best illustrated by comparison with the Ribband Group, the contemporaneous sequence preserved to the south-west in Ireland, which contains several andesitic volcanic intercalations. The composition of these suggests that subduction-related, arc volcanism was coeval with sedimentation during the late Tremadoc and continued intermittently through much of the Arenig. However, since the volcanic influence appears to decrease markedly towards the north-east, the nature of the depositional environment might also change. Any such change would require active subduction to be distanced from the Skiddaw Group’s area of deposition, probably by one or more major transform faults. Hence, any comparison of the depositional settings of the Manx and Skiddaw groups must recognise that they may have been compartmentalised by major structures.

The thickness, duration and geographical extent of the Skiddaw and Manx groups suggest that they were deposited in a large basin (or series of basins) with a long history of subsidence. The
provenance of the Skiddaw Group was largely within an old, inactive, continental volcanic arc lying to the south-east and there is a marked absence of any juvenile volcaniclastic input prior to the Llanvirn. An extensional continental margin therefore seems a more likely site for deposition than an inter-arc or back-arc zone. In this apparent absence of coeval volcanism until late in its depositional history, the Skiddaw Group contrasts with the Manx Group (which contains minor volcanic rocks) and the more distant Ribband Group in south-east Ireland, as discussed above. There is also a major contrast with contemporaneous developments in the Welsh Basin, where there was considerable subduction-related volcanicity during the Tremadoc and Arenig.

Despite the presence of the rare volcanic interbeds, the likely provenance of the Manx Group sandstones was broadly comparable to, but generally more mature than, that of Skiddaw Group sandstones. Petrographical and geochemical evidence suggests a heterolithic source area containing a continental basement, an extinct volcanic arc and a cover of clastic sedimentary rocks. The quartz-arenite units in the Manx Group are probably peripheral representatives of the ‘Armorican’ quartzite lithofacies that was widely developed on the northern margin of Gondwana during the early Ordovician. An analysis of palaeocurrents and facies architecture, shows that all of the Manx Group turbidite succession was derived broadly from the south-east, i.e. from the direction of Gondwana, with the distributory fan systems swinging towards the west within the depositional basin. Again, a general similarity with the Skiddaw Group emerges, though sedimentation of the two groups was probably fed by different distributory systems.

Some idea of the possible basin configuration during Skiddaw Group deposition can be gained from an examination of the widespread slump folds. Within the Northern Fells Belt these are predominantly orientated towards the south-east and although the origin of the larger folds has been questioned there remains evidence of a likely south-east-facing palaeoslope, at least during the Tremadoc and early Arenig. Conversely, south of the Causey Pike Fault in the Central Fells Belt, the Buttermere Formation is a large olistostrome emplaced towards the north-west; only relatively thin debris flow beds are seen in the Northern Fells belt at an equivalent stratigraphical level. From the contrasting scale and style and orientation of the slump movements it seems likely that the depositional basin had a steep, faulted southerly margin.

Palaeocurrent evidence from the Skiddaw Group’s two periods of submarine fan development (essentially the Watch Hill and Loweswater formations) suggests that each occurred within a different basin configuration. During deposition of the first (Watch Hill), axial flow was along a trough orientated approximately east-west. Subsequent deposition (Loweswater) was spatially more complex, with greater influence by sea-floor topography. The latter may have been influenced by syndepositional extensional faults trending north-west to south-east within the depositional basin, with the intervening fault blocks tilted to the northeast. The overall picture that emerges is of a north-facing extensional half-graben system with the major boundary fault (or faults) on the southeastern side. The observed stratigraphical contrast across the Causey Pike Fault would certainly have been made more conspicuous if the basin was originally composite, and so perhaps that structure was initiated as a north-west-downthrowing normal fault partitioning the Skiddaw Group depositional basin. Additional support for this idea is provided by model ages derived from isotope data, which show a marked difference in provenance maturity across the Causey Pike Fault.

The illite crystallinity and clay mineral assemblages of the Skiddaw Group and Manx Group mudstones might also support an extensional basin interpretation. These data suggest that early burial metamorphism, characterised by late diagenetic to low anchizonal grades, occurred under a higher geothermal gradient (at least 35°C/km) than would normally be expected in an ensialic basin and was probably related to high heat flow during crustal extension and thinning. However, there must remain some uncertainty as to the relationship of burial metamorphism in the depositional basin during its putative extension (Tremadoc to Llanvirn), and that during subsequent
suprasubduction zone basin uplift and volcanicity (Llanvirn to Caradoc; discussed below) when a high geothermal gradient would also be expected.

**Bibliography**


