Excursion 6 Afton Water, Hare Hill and Bail Hill: Ordovician submarine fans, antimony and a seamount volcano

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OS 1:50 000 Sheet 71 Lanark 6-Upper Nithsdale

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Route maps: (Figure 27) and (Figure 28)

Main points of interest Thick Ordovician turbidite fan sequence with greywackes, conglomerate, red chert; antimony mineralisation; volcanic rocks and possible olistoliths.

Logistics Access to Glen Afton (Localities 1–3) and Bail Hill (Localities 5–9) involves the use of single-track roads unsuitable for vehicles larger than a minibus. Roadside parking is usually adequate for 3–4 cars. A visit to the Hare Hill antimony mine (Locality 4) involves a 5 km round-trip hike over rough ground with a climb of about 300 m.

Introduction Just south of New Cumnock, the glaciated valley of the Afton Water (the *Sweet Afton* eulogised by Robert Burns) affords one of the best and most accessible inland cross-strike sections in the Ordovician Northern Belt of the Southern Uplands. The section displayed in the vicinity of the Afton Dam is one of the best exposures of conglomerate in the region.

The antimony mine at Hare Hill is one of only two localities in Scotland where stibnite has been found in significant amounts. The other is at Glendinning, near Langholm (Appendix 1).

Around Bail Hill on the NE side of the River Nith near Sanquhar is the most extensive area of volcanic rocks in the Northern Belt of the Southern Uplands. It includes unusual Ordovician lavas containing remarkable, large euhedral phenocrysts of clinopyroxene. An extensive series of basaltic lavas, agglomerates and trachytic intrusions can be seen around Bail Hill itself, while several outlying tuff members are interbedded with the surrounding greywacke succession. The volcanic and sedimentary rocks of the Bail Hill area have been intensively studied by McMurtry (1980a, b, c) and this part of the excursion is largely based on his work.

The Afton Water Section (Figure 27)

Glen Afton is approached from New Cumnock, which lies on the A76. Take the B741 (Dalmellington) road and after about 100 m turn south towards Craigdarroch along the unclassified road on the west side of the Afton Water.

1 Afton Water, Laight: Marchburn Formation greywacke and chert

Park at the memorial to Robert Burns about 400 m south of Laight [NS 614 114]. After paying due homage to Scotland's National Bard, scramble down the west bank of the Afton Water where, if the water level is sufficiently low, interbedded red chert, cherty mudstone, laminated siltstone and greywacke of the Marchburn Formation can be examined in the river. At this locality, close to the Southern Upland Fault, the attitude of the strata is anomalous in regional terms; the beds dip generally east at 20–40°. The greywackes are dull greenish purple, rich in feldspar and contain obvious red grains of chert and acid lavas. They are the finer-grained equivalents of the 'Haggis Rock' microconglomerates which can be traced from Glen Afton NE to Leadburn near Edinburgh.

This locality must be only a few hundred metres south of the Southern Upland Fault (SUF), though in this area the fault itself is overstepped by the Carboniferous rocks of the New Cumnock Coalfield, which cross the fault to rest unconformably on Ordovician strata. A 6 m-wide Tertiary tholeiite dyke trending 070°, parallel to the SUF, can also be examined here.

2 Lochingirroch Burn and Bolt Burn: Kirkcolm Formation greywackes

Continue south on the public road for a further 2 Iml and park near Lochingirroch Farm [NS 622 094]. Walk up Lochingirroch Burn where thick sequences of rhythmic, parallel-bedded 'flysch' sandstone and hemipelagic mudstone can be examined. These are classical turbidites of the quartzrich Kirkcolm Formation and display many good examples of internal Bouma sequences (Figure 6) including graded bedding and parallel and cross-lamination. External sedimentary structures such as flute and groove casts, flame structures and loaded bedding can also be seen. In areas where fold hinges may not be visible, sedimentary structures can often be used to show reversals of younging direction and thus provide evidel1Ce of folding. Happily, however, the flaggy type of lithology in Lochingirroch Burn appears to fold particularly well and the hinges of numerous small-scale steeply plunging folds (probably D3) can be seen.

After about 800 m exposure becomes poor. Return to the road and drive south For a further 1 km to Bolt Burn Bridge [NS 629 085]. Walk up Bolt Burn to examine another good section in quartzose turbidite sandstones of the Kirkcolm Formation, with further examples of D3 folding. The prominent Boltcraig Hill , immediately to the south, consists of massive greywackes of the Blackcraig Formation. These are best examined at the next locality.

3 Afton Darn: Blackcraig Formation greywackes and conglomerates

From Bolt Burn Bridge, continue south along the public road as far as the entrance to Afton Waterworks, where, with the permission of the superintendent, it should be possible to park at the filterhouse [NS 627 056]. Walk south from here for about 600 m along the private road towards the dam, to examine the rocks in the spillway and the bed of the Afton Water downstream. This 1 km-long section is one of the best exposures of massive greywackes and associated boulder conglomerates in the entire Southern Uplands. It forms part of the type section of the Blackcraig Formation (Floyd, 1982), a 1500 m-thick sequence of thickly bedded greywacke-turbidites and conglomerates with a distinctive petrography. The greywackes and the matrix of the conglomerates contain large amounts of epidote, pyroxene and amphibole, which are often abundant enough to impart a distinct dark green colour to freshly broken rock surfaces.

The prominent crags of Craigbraneoch Hill, Castle William and Black Hill are formed by the base of the formation, whose massive greywackes resist erosion better than those of the Kirkcolm Formation to the south, and effectively form the natural barrier across Glen Afton now utilised by the dam. Downstream, in the distance, the steep western flank of Blackcraig Hill displays excellent large-scale bedding Features dipping steeply towards the north, with an obvious low-angle thrust dipping gently northwards and visibly displacing some particularly massive beds.

In the vicinity of the dam, the beds strike generally 065° and both dip and young towards the NW The lower part of the succession consists of 300 m of massive, thickly bedded coarse-grained greywackes with sporadic pebbly patches. These are succeeded by about 170 m of coarse-grained greywackes and boulder conglomerates in units up to 7 m thick. Some of these thick beds effectively form large-scale 'mega-Bouma' units, with an internal sequence of grading, parallel lamination and trough cross-stratification. The latter feature, together with basal scours and cobble imbrication, consistently indicates sediment transport from the NW, across the structural trend of the Southern Uplands.

Most of the conglomerates contain wellrounded boulders of extra-basinal origin, up to 1.5 m in diameter, including granite, gabbro, porphyry, basalt, vein quartz, quartzite, chert and siltstone. The presence of rare boulders of conglomerate suggests that much of the extra-basinal material may be polycyclic, derived from older conglomerates, and this may account for the variety of clasts and their high degree of rounding. Channelling at the base of rudite units gives a good indication of the erosional potential of the fast-moving, powerful and boulder-charged turbidity currents and debris flows which must have transported these sediments.

A few of the conglomeratic units contain only intrabasinal clasts, angular blocks of greywacke and dark siltstone. The greywacke clasts are petrographically identical to the enclosing greywacke, suggesting that they were eroded from the walls of channels cut into partly lithified units of the Blackcraig Formation on the submarine fan itself, rather than from the walls of the feeder canyon. Clasts which preserve bedding sometimes show differential rounding or erosion of their sandstone-siltstone layers, again suggesting that they were only partly lithified during their brief clastic existence.

The granite boulders in the Blackcraig conglomerate were studied by Elders (1987), who identified at least three distinct petrographical suites which were dated by the Rb/Sr method. In Glen Afton, the oldest suite consists of weakly foliated biotite-bearing granites which gave an age of 1231 ± 120 Ma. A suite of muscovitebearing granites gave an age of 702 ± 86 Ma while a group of hornblende-biotite granites yielded an age of 49 1 ± 14 Ma. Elders investigated possible source areas for these rocks in Newfoundland, where granites of similar composition and age patterns are found, and used this to suggest a sinistral strike-slip fault movement of the order of 1500 km between the Southern Uplands and Newfoundland.

Traced both laterally (along-strike) and downstream (across-strike and up-sequence), the proportion of conglomerate gradually declines until the succession consists only of the coarse-grained sandstone which forms the matrix of the conglomerates. At the top of the succession, in the vicinity of Blackcraig Farm [637 080], the formation becomes quite thinly bedded and consists of fine-grained flaggy greywackes which still, however, retain the distinctive petrographical character of the underlying more massive beds.

A detailed sedimentological study of the Blackcraig Formation was carried out by Holroyd (1978) who compared the conglomerates with those at Corsewall Point (Excursion 15, Locality 2) and Craighit (Excursion 7, Locality 5). Overall, the Blackcraig Formation was interpreted as a mid-fan facies deposit, with the lower conglomeratic portion deposited within major channels, up to 2.5 km wide, in the proximal mid-fan region.

Hare Hill (Figure 27)

4 The Knipe: antimony mineralisation

From Glen Afton, drive back to New Cumnock and take the A76 east towards Kirkconnel and Dumfries. About 3 km beyond New Cumnock, park in one of the roadside lay-bys near Polshill Farm and walk south up the Garepool Burn. At the sharp bend where the general course of the burn changes from east to north, walk SW away from the burn for about 300 m across a peary plateau towards the old trial workings [NS 658 105] on the hill slope beyond.

The stibnite (Sb_2S_3) vein on Hare Hill has been known since the 1840s when a small trial mine was driven along it. The vein is located within the small granite intrusion of The Knipe (Dewey et al., 1920). This late-Caledonian pluron is about 1.5 km in diameter and consists of a fine-to medium-grained, slightly porphyritic biotite-hornblende granite. It is intruded into Ordovician greywackes of the Kirkcolm Formation, which have been baked to form a thermal aureole of hard purple hornfels.

Mine abandonment plans (held by the BGS) show that the adit was 55 m long, with an initial trend of N035° near the entrance, swinging to about 020° after some 30 m. A raise was driven up to the surface about 18 m inside the runnel, and the vein exposed and worked down from the surface. The vein was vertical and said to range from 30 to 55 cm wide, though was reportedly lost after about 37 m into the hillside. Some roof falls have occurred and the mine is now silted lip and inaccessible. Water is drained off via an iron pipe and used as a water supply.

There is a heap of mine spoil including vein material lying at the tunnel entrance. Mineral specimens show needles of metallic grey stibnite in a white vein-quartz matrix, though in places the stibnite has weathered to a yellow ochreous crust, probably the antimony oxide, cervanite ($Sb_2O_3.Sb_2O_5$).

A second stibnite vein, which had been reported in estate papers From the 1840s, was relocated by the author in 1971, some 750 m west of the trial mine. The second locality [NS 6507 1032] lies on the east bank of the Blackdams Burn and is marked by obvious signs of earlier trenching and small overgrown spoil heaps. The vein material consists of grey stibnite needles set in white chert-like quartz; blocks can be found in the burn.

The Hare Hill area was intensively prospected between 1982 and 1988 by BP Minerals (Boast et al., 1990) who found indications, both within the granite and at the intrusive contact, of gold mineralisation associated with a zoned As-Sb-Cu-PbZn hydrothermal assemblage. Disseminated and vein-type mineralisation both occur, the latter though t to be controlled by the intersection of north-south and ENE (Caledonoid) trending fractures.

Bail Hill

From Hare Hill, return to the A76 and continue south towards Dumfries. About 4 km beyond Kirkconnel, at the large bridge over the Crawick Water just beFore the town of Sanquhar, turn left on to the B740 towards Crawfordjohn. After about 200 m, and just before the railway bridge, turn left on to the single-track road which gives access to the Bail Hill area [760 143]. Roadside parking for cars/minibuses is possible in the vicinity of Bail Hill and Localities 5–8 can all be reached by walking From there. Locality 9 is best approached From the B740.

The Bail Hill Volcanic Group consists of an extensive pile of highly porphyritic autobrecciated lavas and pyroclastic rocks of Ordovician age (McMurtry, 1980a, b, c; Hepworth et al., 1982) whose early basaltic stages (Cat Cleugh Formation) were erupted on to black graptolitic shales (Locality 7). Later lavas and agglomerates of hawaiite and mugearite composition (Peat Rig Formation and Grain Burn Member -Locality 5) make up the bulk of the volcanic succession and the whole pile was finally intruded by a volcanic neck, now infilled with lava (Bught Craig Member - Locality 6).

Outlying pyroclastic members crop out in a series of burns NE of Bail Hill. They consist of crystal and lithic tuffs and agglomerates which interfinger with greywackes and siltstones of the Kiln Formation (Localities 8 and 9). The Bail Hill volcano may be envisaged as a seamount, initially extruded on to a sea floor of black shales, whose magma evolved on the basalt-hawaiite-mugearitetrachyte mildly alkaline trend. As the lava and pyroclastic pile built up, the volcano was gradually swamped by submarine fan sediments until the volcano finally became extinct and was buried under coarse-grained proximal terrigenous deposits.

5 Grain Burn: lavas and agglomerates

From the road near Bail Hill, walk west about 100 m into the headwaters of Grain Burn [NS 753 142] and traverse downstream. In this area hawaiite/mugearite lavas and agglomerates of the Peat Rig Formation can be examined. The lavas contain phenocrysts of feldspar (oligoclase/andesine), amphibole (pargasite), apatite and biotite/ phlogopite. Hawaiite lavas of the Grain Burn Member also crop out hereabouts in the burn.

6 Bught Craig: infilled volcanic neck

From Grain Burn, walk about 1 km SE across the moor towards Bught Craig [NS 757 135] near the head of the west branch of Cat Cleugh, in which the Bught Craig Member is exposed. This volcanic unit is thought to represent an infilled volcanic neck which had previously fed the Bail Hill volcano but then became choked with blocks of igneous material and lava. At its type locality, the rock consists of a hawaiite lava matrix containing fragments of coarseand fine-grained igneous rocks including gabbro, diorite and a variety of lava and dyke lithologies. Some of the clasts cannot be matched with rock types presently exposed at Bail Hill, suggesting that the volcanic edifice was formerly more diverse and extensive than at present.

7 Cat Cleugh: euhedral clinopyroxenes

Continue downstream in Cat Cleugh [NS 757 134] for about 100 m to examine basaltic lavas of the Cat Cleugh Formation. The lavas are autobrecciated and contain large euhedral black clinopyroxene (salite) phenocrysts up to 16 mm long. The pyroxene crystals are beautifully twinned, commonly visibly curved and display 'hourglass' zoning under the microscope. They are set in a green fine-grained lava matrix which also contains small phenocrysts of altered plagioclase and zeolite-filled amygdales. The lava matrix is soft and the pyroxenes can often be extracted without difficulty, leaving perfect casts of the crystals in the matrix.

Proceed downstream for another 150 m to examine the base of the Bail Hill volcanic succession, where weakly porphyritic basalt lavas can be seen resting conformably on black shales. These contain a *Nemagraptus gracilis* Biozone fauna (mid-Ordovician) and correlate with the lower part of the Glenkiln Shales of the Moffat Shale Group. Downstream from the black shales, two trachytic intrusions can be seen in the next 150 m before the Ordovician section ends near the junction of the two branches of Cat Cleugh. Exposures of sandstone with plant fragments, grey mudstone and coal at this point belong to the Carboniferous sequence in the Sanquhar Coalfield. Although the basin has the overall structure of a

NW-trending half-graben, the Sanquhar Fault forming its NE boundary appears to have been overstepped here by Carboniferous strata, with no evidence seen in Cat Cleugh for any large-scale faulting.

From Cat Cleugh, return to the road at Bail Hill. This forms a convenient break in the excursion; the next locality involves a 2.5 km hike across rough moorland.

8 Stoodfold Burn: lithic tuffs and siltstones

Starring from the road 500 m south of the summit of Bail Hill, walk about 600 m east to Stood fold Burn [NS 767 138] and traverse downstream. In Stoodfold Burn, close to its confluence with Kiln Burn, the outlying hawaiite/mugearite lithic tuffs and agglomerates of the Stoodfold Member can be examined. The ruffs interfinger with siltstones of the Kiln Formation and were derived by submarine grain-flow during pyroclastic activity on the adjacent Bail Hill volcano. Lithic fragments include lavas containing phenocrysts of amphibole, plagioclase, biotite/phlogopite and apatite. Similar lithic and crystal tuffs together with agglomerate and volcaniclastic mudstone are interbedded with fine-grained sandstone and siltstone of the Kiln Formation at its type section in the adjacent Kiln Burn [NS 769 138]. Return to the vehicles and drive back down to the B740. At the junction, turn left (NE) under the railway towards Crawfordjohn and continue for about 4 km to just beyond Carco Farm.

9 Spothfore Burn: Glenflosh, Kiln and Spothfore formations; greywackes, conglomerates and tuffs

On the B740 Crawick to Crawfordjohn road, park a short distance east of Carco Farm and walk up Spothfore Burn from the bridge near its confluence with the Crawick Water [NS 792 141].

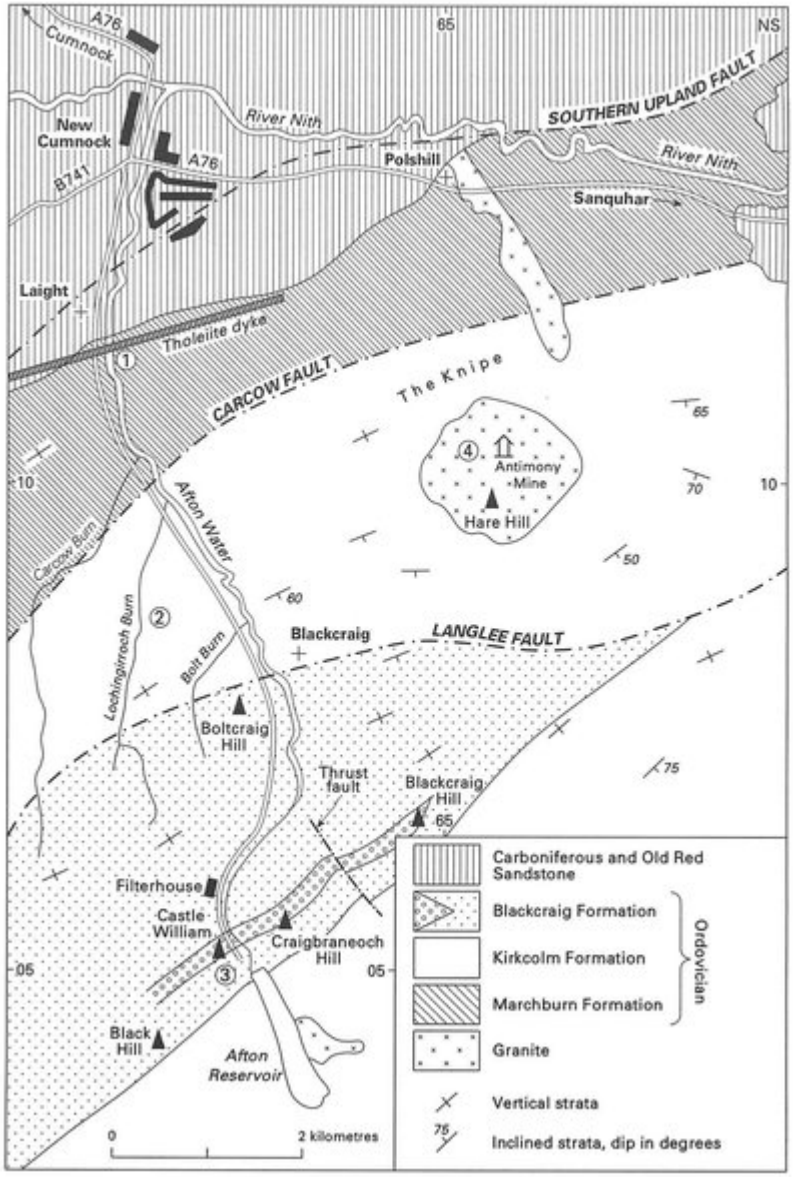
The lower 800 m of the burn traverses quartz-rich greywackes of the Glenflosh Formation before crossing the Eller Fault into the black shales and chert (Moffat Shale Group) which underlie the Kiln Formation (Figure 28). Continuing upstream, hawaiite/ mugearite tuff and agglomerate of the Stoodfold Member are seen interbedded with the fine-grained strata of the Kiln Formation. Close by in the Penfrau Burn tributary, interbedded tuffs of the Penfrau Member are of basaltic composition.

About 200 m upstream from Penfrau Burn, the thin-bedded sandstones and siltstones of the Kiln Formation are succeeded conformably by the much coarser-grained Spothfore Formation. Lithologies include boulder conglomerate, pebble breccia, granule sandstone and siltstone. Clasts range in size up to several metres diameter and are entirely of intra-basinal origin: about 95 per cent of them are of sedimentary material such as greywacke, siltstone or chert, with volcanic rocks making up the balance. The rather disorganised nature of many of the conglomerate beds suggests emplacement by a debris-flow mechanism, with occasional imbrication evidence indicating flow towards the SE.

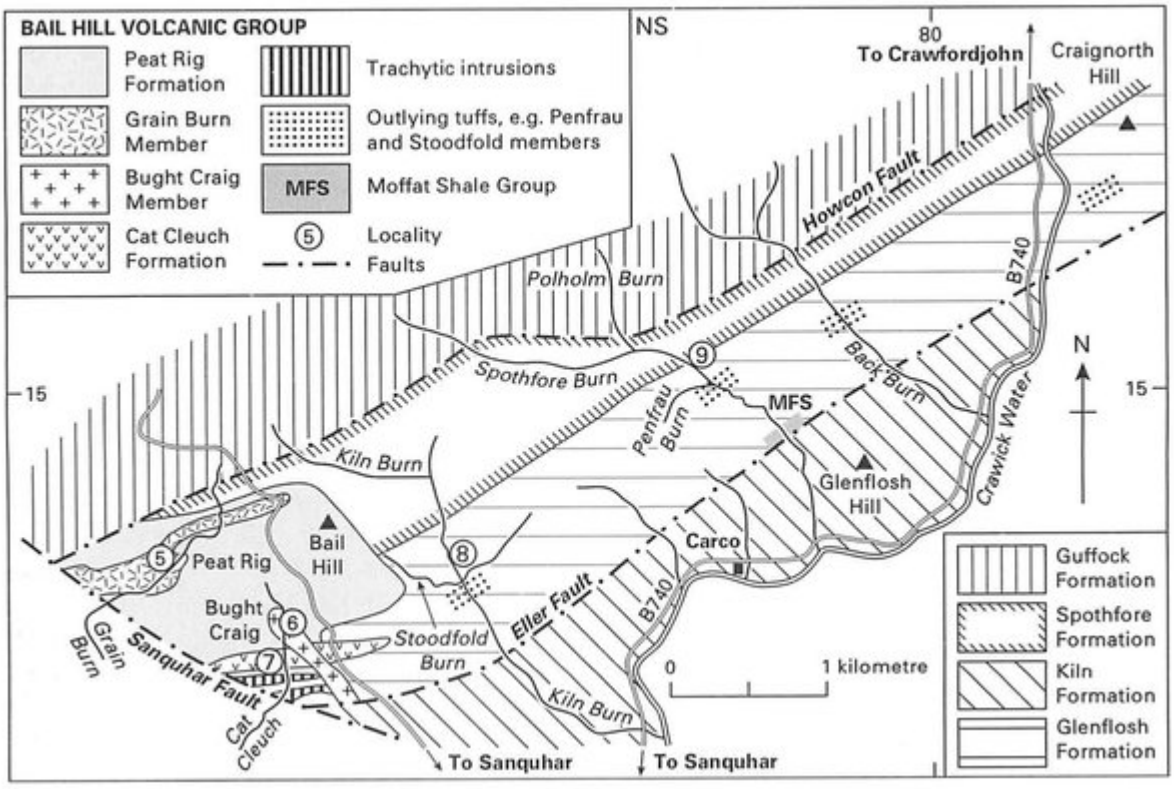
In Spothfore Burn, several large chert bodies (tens of metres in size) can be seen for about 200 m downstream from the junction with Polholm Burn. Features such as bedding oblique to the regional trend, randomly orientated internal folds, and sharp irregular contacts with the surrounding greywacke, have led to these chert bodies being interpreted as large gravity-emplaced olistoliths which have slid downslope or been eroded from the walls of a submarine canyon.

Along strike to the NE, additional outlying hawaiite/mugarite tuffs and agglomerates of the Back Burn and Craignorth members are interbedded with siltstones of the Kiln Formation in Back Burn [NS 794 155] and on Craignorth Hill [NS 811 163] respectively (Figure 28), though these localities are not included in this excursion.

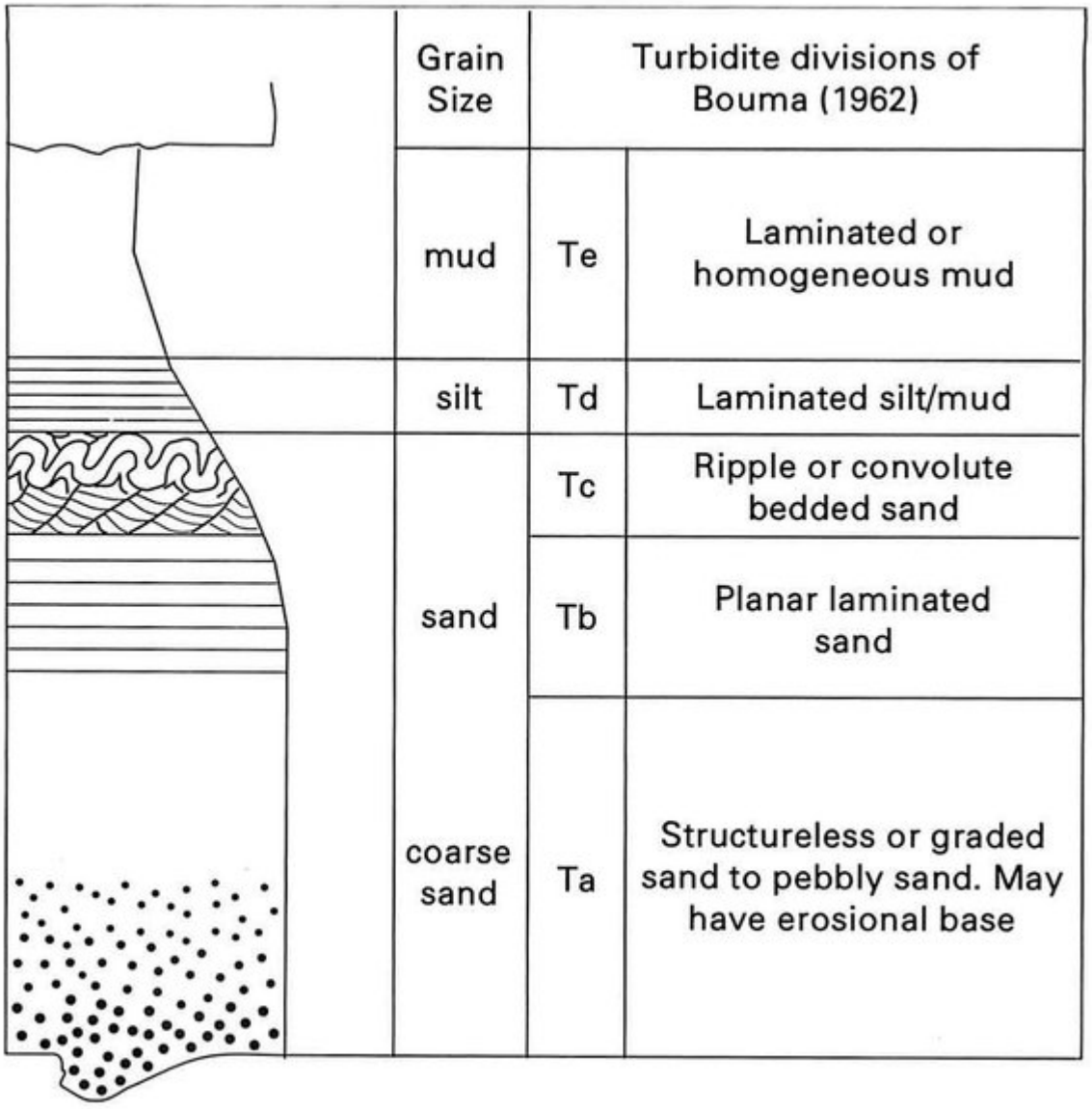
References



(Figure 27) Locality map and outline geology for the Afton Water section and Hare Hill (after Floyd, 1982).



(Figure 28) Locality map and outline geology For the Bail Hill area (after McMurtry, 1980a).



(Figure 6) Divisions within an idealised turbidite bed after Bouma (1962) and Pickering et al. (1989).