# Excursion 9 Dumfries: a Permian desert

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OS 1:50 000 Sheet 84 Dumfries, Castle Douglas 6- surrounding area

BGS 1:50 000 Sheet 9E Thornhill

Route map: (Figure 33)

***Main points of interest*** Aeolian dune sandstones and flash-flood breccias of the Dumfries Basin. The objective of this excursion is to build a picture of the varied desert environment that existed in south-west Scotland during the early Permian, around 270 million years ago.

***Logistics*** The Permian rocks of the Dumfries Basin are examined at five localities in this itinerary, making up a full day's excursion. There is good vehicle access, to within a few hundred metres, at all localities. However, if a coach is used a little more walking will be required at localities 2 and 4. Many more localities are detailed by Brookfield (1981). Permission to visit the Locharbriggs Sandstone Quarry, Locality 1, must be obtained in advance from Baird and Stevenson Ltd, Locharbriggs Quarry, Locharbriggs. **This is** a **working quarry and a hard hat should always be worn.** Permission for access to the railway cutting at Doweel Farm, Locality 2, must be requested at the farmhouse. There is free public access to Castledykes park in Dumfries, Locality 3, during daylight hours. At the time of writing access to the disused Craigs Quarry, Locality 4, is unrestricted. Observation of the riverside outcrops near Glencaple, Locality 5, is most easily undertaken at low tide; **extra care should be taken when the river level is high.**

## Introduction

During the Carboniferous, the Lower Palaeozoic rocks of the Southern Uplands formed an uplifted massif. Fault-controlled depositional basins were filled by deltaic and shallow marine sedimentary rocks and lavas. Change from a coastal setting to a more arid, terrestrial environment occurred at the end of the Carboniferous, and rocks of Lower Palaeozoic to Carboniferous age were unconformably overlain by a 'red-bed' sequence deposited in the desert environment of early Permian times.

The Dumfries Basin is a synclinal half-graben structure bounded to the west by a NNW-trending fault (Figure 33). Synsedimentary movement across the fault uplifted the basement rocks to the west and influenced the depositional facies of the Permian strata. The sequence of Permian aeolian sandstones and breccias within the basin is up to 1600 m thick and unconformably overlies Silurian turbidites and the early Devonian Criffell granodiorite.

Many sedimentary processes are active in a desert environment and produce rocks with different characteristics. Nature and thickness of bedding, grain size, grain shape and roundness, the presence of clasts, the clast lithology and sedimentary structures are all used to infer the depositional processes. A hand lens will be needed to look at specimens and a compass-clinometer to measure the orientation of bedforms which can reveal the direction of migration of the Permian dunes. Comparison of the various Permian rock types will demonstrate the variety of sedimentary processes active in the Dumfries Basin during the Permian.

## 1 Locharbriggs Quarry: dune-bedded desert sandstones

Locharbriggs Quarry is beside the A701, 4.5 km NE of Dumfries, to the north of the village of Heathall. The entrance to the quarry and workshops is on the west side of the road [NX 994 810] and is marked by a red sandstone wall bearing the name of the quarry. There is a car park for visitors with ample space for coaches.

This is a working quarry which extracts blocks of stone for building and ornamental work. **Within the quarry a hard hat must always be worn.** Watch out for any machinery that may be around and note that **some of the faces will be steep**

**so take care.** Because the stone is being continually quarried, the faces that can be seen will vary. Two quarries remain; the northern one is largely disused but the southern one is being actively worked. Go first to the northern quarry and take some time to look at the old face from a distance. Note that extensive curved and planar beds produced by large-scale dunes can be traced over about 5 m.The many cut blocks around provide an opportunity to look at the lithological characteristics of the rock using both the naked eye and a hand lens. It is red in colour due to a haematite coating on the individual grains. Close examination shows that it is a sandstone composed of grains varying in size from fine to coarse. Within any individual bed the grains appear to be well sorted but there is a considerable contrast in grain size between different beds. Grains in the beds of fine-grained sandstone are subrounded to subangular, whereas the grains in beds of coarser sandstone are usually well rounded, with individual grains having a frosted appearance. Most of the grains are glassy quartz but some highly altered; milky white feldspar is also present.

A closer look at the worked face in both quarries will allow a more detailed analysis of the dune bedforms. The orientation of the large-scale cross-beds can be recorded by measuring the strike and the amount of dip. These data are useful in reconstructing the environment and geometry of the features. An individual cross-bed, called a foreset, can have a dip of anything up to 35° but tracing this downwards the dip will decrease, curving into the underlying surface.

Individual foreset beds, usually up to 10 cm thick, have a wedge-shaped geometry with little internal structure. Tracing one of these beds laterally shows that it thins down the dip of the foreset. Finely laminated beds may be seen, usually where the dips are low. Small-scale cross-beds, similar to subaqueous ripples may also befound. These may be in areas of low dip or on top of larger foresets.

The cross-beds are commonly truncated by lower-angle planes, called bounding surfaces, which define cross-bedded units that may be 0.1 m to 10 m thick. A hierarchy of bounding surfaces can be built up, in which the first-order surfaces, those lying closest to horizontal, cut all other surfaces. These relationships are shown diagrammatically in (Figure 34). The bounding surfaces are frequently associated with removal of the red colouration from the rock on either side. This may be due to the passage of groundwater leaching out the red haematite.

**Environmental interpretation** The characteristics of the individual sand grains, particularly the high degree of sorting, the roundness and the frosted appearance, suggest that these grains were transported by the action of wind. Transport by wind is highly selective, with grains being either removed or deposited depending on their size and the velocity of the wind. Individual beds are therefore well sorted but, with changing wind velocity, the size of the transported grains will be either coarser or finer, hence the successive beds of differing grain size. Wind transport is also responsible for the rounding of individual grains and for producing the characteristic frosted appearance.

The scale of the sedimentary structures suggests that these beds were deposited as large dunes. The gently dipping side of the dune (the stoss side) faces into the wind and grains are being continually moved upwards towards the crest. The steep side of the dune (the lee side) is the site of successive avalanche flows as the dune migrates down wind. The large-scale cross-beds are the preserved foresets on the lee side of the dune formed by this process. The wedge-shaped beds with no internal structure represent the individual avalanches, each formed as a single event. Each dune was stabilised then overtaken and eroded during the deposition of a subsequent dune, resulting in truncation at the top of the dune and the development of a first order bounding surface. Very large dunes will have smaller dunes migrating, piggy-back over them, creating second-and third-order bounding surfaces (Figure 34). These relationships will be seen again at Locality 4.

The geometry of the dunes can be deduced using the orientational data gathered by measuring the dips and strikes of the foresets. These represent the orientation of the lee slope of the dune, the most steeply dipping foresets giving the most accurate orientation. The stoss side of the dune is rarely preserved as this is where erosion takes place (Figure 34). Low depositional dips are typical of interdune areas, where sediment may accumulate by the accretion of particles stuck together by moisture from dew or from rising groundwater. Grainfall lamination will be present at the dune margins where avalanching is not present. Wind-blown ripples may be preserved on the dune surface sand and are commonly transverse to the dune crests. The tracks of any passing animal may be preserved in the interdune deposits. Footprints of an early reptile, a forerunner of the Jurassic and Cretaceous dinosaurs, have been found in these rocks (McKeever, 1994).

## 2 Doweel Farm railway cutting: alluvial fan breccias

Permian sedimentary rocks deposited on the west side of the Dumfries Basin are well exposed in an old railway cutting at Doweel Farm [NX 938 739]. From Locharbriggs Quarry turn right from the main entrance to the quarry on to the A701 and drive approximately 3 km SW to the junction with the Dumfries ring road. Turn right on to the ring road and travel 4 km west, following signs for A75 to Stranraer. At the end of the ring road turn right on to the A75 and, after only 500 m, turn left on to a minor road signed to Cargenbridge. Drive past the ICI chemical works to a T-junction with the A711 and turn right in the direction of Dalbeattie. Drive 1 km and turn off, to the right, on to a minor road. The entrance to Doweel Farm is a narrow driveway on the left. Park in the farmyard after arranging access permission. Coach parking is best on the roadside after the turn from the A711. Walk south through the farm to the line of the old railway, turn and walk west along the cutting.

The cutting is 500 m long with sedimentary breccias exposed in its vertical sides. The breccia clasts are angular and poorly sorted, from a few millimetres to about 30 cm across, and supported in a matrix of fine-grained, reddish coloured sandstone. The clasts are of turbidite sandstone and shale, thermally metamorphosed turbidite lithologies and finely crystalline intrusive acid igneous rocks. Breccias dominate the exposure but thin units of red sandstone can also be seen which are lenticular, usually less than 10 cm thick but many metres in lateral extent. The sandstones are thinly bedded, fine grained and mostly of red quartzose sand with small clasts of turbidite sandstone and shale. A hand lens reveals that a few of the quartz grains are very well rounded.

There is a crude alignment, or imbrication, of the breccia clasts; they 'dip' in a westerly direction. Bedding within the breccias is defined by the thin sandstone layers but within each thick breccia unit there is an upward decrease in grain size. Pockets of large cobbles may also be present between the breccia units.

**Environmental interpretation** The breccias at Doweel Farm were not deposited by the same processes as the fine-grained aeolian sandstones at Locharbriggs Quarry. Transport of the coarse-grained breccia clasts and their deposition in thick beds indicates a very energetic sedimentary environment. The beds are tabular, with no evidence of channelling. The nature of each bed, grading up through breccia into fine-grained sandstone, demonstrates a single depositional event waning in strength, probably a sheetflood on an alluvial fan in a desert valley (wadi). The pockets of cobbles may have been concentrated by the first surge of each sheet flood event (Brookfield, 1980). Imbricated clasts 'clip' in an up-flow direction; flow at Doweel was, therefore, eastwards. The breccia clasts are of local derivation; Silurian turbidites are exposed 300 m further west in the next cutting and the Doweel cutting is only 1.5 km from the metamorphosed aureole of the Criffell granodiorite. Clasts of fine-grained, acidic, igneous rocks may have been eroded from the many dykes that locally intrude the Silurian turbidites. The rare occurrence of well-rounded aeolian quartz grains in the sandstone tops of the sheetflood units indicates the existence of contemporary windblown sands.

Arid desert environments are subject to rare, heavy rainstorms. High runoff, in an area devoid of vegetation, causes flash floods. We can envisage that storms of this sort eroded rocks from the uplands west of the basin and swept the debris eastwards down a desert wadi. The breccias were deposited as the floods slowed and spread out over the wadi floor. Fault-controlled relative uplift of the Lower Palaeozoic basement at the western margin of the basin during the Permian ensured a constant supply of debris.

Alluvial breccias dominate the west side of the Dumfries Basin and are named the Doweel Breccia Formation after the type exposure in this railway cutting (Figure 33). A borehole drilled within the ICI chemical works at Cargenbridge recovered approximately 200 m of breccias; bedded mudrocks and sandstones are present only at the base of the core (Brookfield, 1978). Waterlain breccias and aeolian sandstones interfinger where sheetflood deposits from the west side of the Dumfries Basin periodically prograded into the dune fields in the centre of the basin. The relationship between the waterlain and aeolian deposits is examined at the next locality.

## 3 Castledykes Park, Dumfries: alluvial fan breccias and the relationship with the dune-bedded sandstones

Castledykes Park, Dumfries [NX 976 746] is a public park in the town of Dumfries. From Doweel Farm, return to the A711, turn left and drive 3 km into Dumfries. In the town you will see many splendid buildings constructed of the red aeolian sandstone from Locharbriggs Quarry. Cross the River Nith over New Bridge and turn immediately right on to White Sands. Drive to the junction controlled by traffic lights at St Michael's Bridge, turn left on to St Michael's Bridge Road and almost immediately right on to St Michael Street. Drive 300 m along St Michael Street to a roundabout and turn right on to Nith Bank (B725), then fork right on to Kingholm Road (B726) down to the bank of the river Nith. Park on the right side of the road. Enter Castledykes Park by the south gate which is on the left side of the road. The rose garden has been developed within an old quarry in which aspects of the Permian environment can be studied. In particular, this quarry shows the relationship between aeolian dunes, of the type seen at Locharbriggs, and alluvial fan breccias like those in the railway cutting at Doweel Farm.

The north face of this old quarry demonstrates the relationship between the rocks deposited in different environments. At the east end of the north face (extreme right-hand side) the lithologies that were seen at Locharbriggs can be identified. These are red well-sorted sandstones with high-angle cross-bedding and with individual grains showing the diagnostic well-rounded and frosted characteristics of wind-blown sediments. Below this unit are less well-sorted sandstones with only small-scale cross-bedding. These sandstones also contain flecks of white mica (muscovite) and are interpreted as fluvial deposits.

Above the aeolian sandstone the rock has a different character entirely. Most of the face is made up of a coarse breccia with cobbles up to 0.30 m in diameter. The base of the breccia bed is erosive, cutting through both the aeolian and the fluvial sandstones. The conglomerate is poorly sorted, the clasts are mostly matrix-supported and finer-grained material surrounds each of the larger clasts. The breccia clasts are mostly turbidite sandstone but some felsite and distinctive blocks of granite are also present.

**Environmental interpretation** The interpretation of this quarry helps build a more complete picture of Permian sedimentation in south-west Scotland. Again, as at Locharbriggs, some aeolian dune-bedded sandstones are present. The contrasting micaceous sandstone was deposited under fluvial conditions in a river or stream indicating that streams did flow through the area at times. The coarse-grained conglomerate demonstrates a dramatic change in environment. For these rocks to be deposited, a high-energy environment is needed with rapid transportation and deposition to prevent sorting of the clasts. In contrast to the environment inferred at Doweel, there is a well-defined channel filled with poorly sorted breccias and overlain by sheet flood deposits. These were most probably deposited by a flash flood flowing down a channel cut through the underlying sediments during a previous flood. Clasts within the breccia illustrate the lithologies that were at outcrop around Dumfries in Permian times. Most of the lithologies can be identified at the surface today (Figure 1) and (Figure 8) suggesting that the present landscape is not much different from the Permian one. Either there has been little erosion since Permian times, or the Permian landscape has been re-excavated by post-Permian erosion.

## 4 Craigs Quarry: cross-section through a Permian dune

A cross-section through a Permian dune is exposed at Craigs Quarry [NX 998 743]. From Castledykes Park drive back (north) up Kingholm Road (B726), turn left at the junction with Nith Bank (B725) and return to the roundabout junction. Turn right on to Craigs Road and follow it for 700 m. The road bends round to the left and becomes Gillbrae Road. Continue for 800 m to a T-junction and turn right on to Georgetown Road. Follow this for 800 m through a residential area; beyond the junction with Calside Road, the road becomes much narrower. If you are travelling by coach, park on the roadside just before Calside Road and continue to Locality 4 on foot. Cars may continue a further 900 m along Georgetown Road, carrying straight on at the crossroads at Undercraigs. Craigs Quarry is to the west (right) of the road. There are two entrances; take the second entrance opposite the house named The Knowe [NY 000 743]. Turn right into the quarry entrance and drive or walk to the north corner of the quarry. Craigs Quarry has previously been used as a landfill site **so appropriate care should be taken.**

Dune sandstones are exposed in two faces, roughly at right angles, at the NW corner of the quarry. The faces are more than 10 m high and expose a cross-section through a dune. Curved chisel marks pit the surface of the face, a relict of previous quarrying techniques. Reptilian footprints have been recorded from the dune sandstones from this quarry

(Harkness, 1850).

Examined closely, the red sandstones appear well sorted and either coarse or medium grained (about 0.5 to 1 mm). The sand grains are mostly quartz; they are well rounded and frosted, typical of wind-blown sands. The sandstone is thinly bedded, with beds defined by the grain size variation from coarse to medium. The two faces, at approximately 90°, not only give an insight into the considerable size of the dune bed-forms but also reveal their three-dimensional geometry. A subhorizontal first-order bounding surface (Figure 34) is exposed in both faces just above the present-day floor of the quarry. In the north face, west-dipping cross-beds defined by variations in grain size are planar in their upper parts but curve down to meet the first-order bounding surface. In the strike-section of the west face this curvature is much exaggerated. A second, gently inclined first-order bounding surface is present at the top of the north face. Cross-beds beneath this surface are truncated.

In the corner between the faces, about 4 m above the quarry floor, a second-order bounding surface is exposed. It is marked by a thin horizon of more fine-grained rock. In the north face it dips to the west and truncates the underlying cross-beds. Traced round to the west face the second-order bounding surface becomes subhorizontal and the angular discordance with the underlying cross-bedding is.more marked. Note the contrast in dip of cross-bedding above and below the second-order bounding surface in the west quarry face. Another, parallel, second-order bounding surface extends from the eastern edge to the centre of the north face.

**Environmental interpretation** The exposures at Craigs Quarry demonstrate the large scale of dune structures developed during the Permian in the Dumfries Basin. The largest aeolian dunes, or draas, are estimated to have been 100–250 m in height (Brookfield, 1977a; 1980). Cross-beds above the first-order surfaces record the westward migration of a draa structure. Erosion of the draa and migration of smaller dune structures across it is evident from the second-order bounding surfaces and overlying cross-bedded sandstones. Migration of these dunes was oblique to the main draa structure as demonstrated by the change in orientation of cross-bedding below and above the upper second-order surface in the west face. The change in orientation of cross-bed fore-sets does not, necessarily, imply a change in the predominant wind direction. Dunes can be complex structures with cross-beds orientated at many angles to the predominant wind direction.

## 5 River bank, Glencaple: alluvial breccias of granitic clasts

The last locality is near Glencaple. From Craigs Quarry drive south along Georgetown Road for 400 m and turn right on to another minor road. Turn left where this road meets a T-junction and drive 3 km south then take a right turn to Glencaple. In Glencaple turn left on to the B725. This route follows narrow, minor roads suitable only for small vehicles. If you are travelling by coach, go back into Dumfries and take the B725 to Glencaple at the roundabout junction. From Glencaple drive south along the B725 and park by the road 300 m south of the village. Outcrops of Permian rocks lie to the west of the road, in the estuary, just above high water mark [NX 995 681].

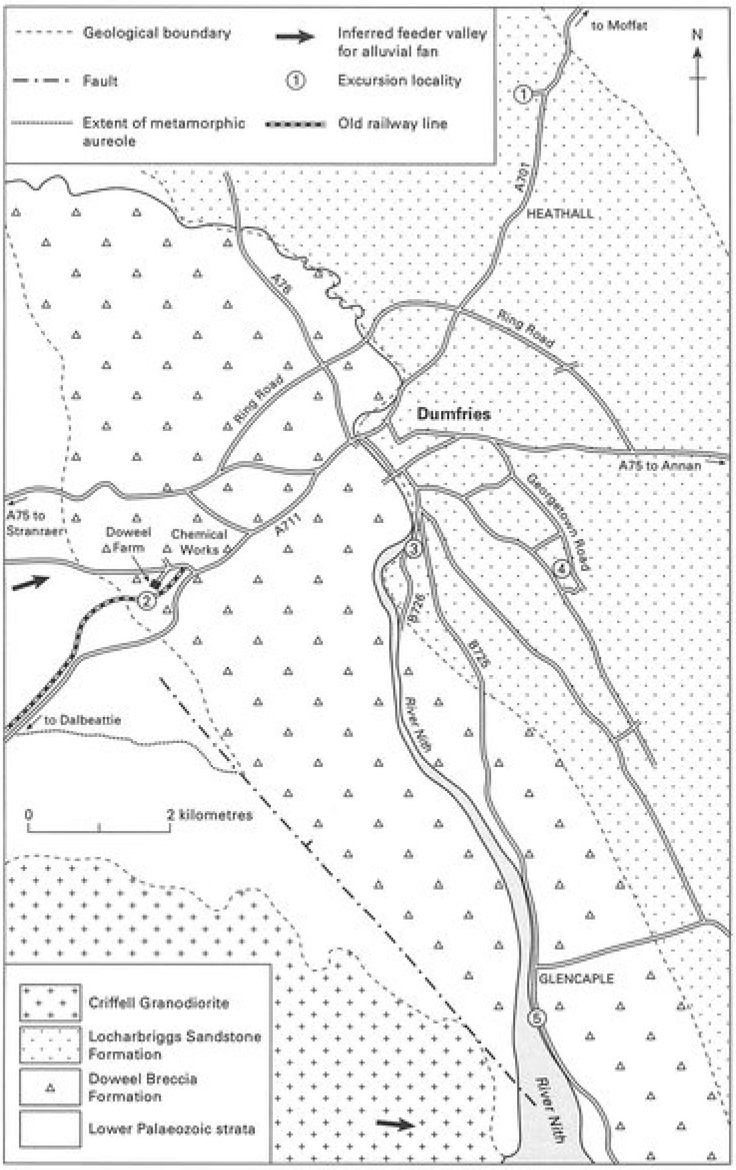
Now-familiar Permian sedimentary breccias are exposed in a small shore section in the east bank of the River Nith. Angular clasts of a granitic lithology, first noted in the exposures in Castledykes Park, are predominant. Clasts of metamorphosed turbidite sandstones and mudrocks are common, but fragments of unmetamorphosed turbidite lithologies are also a minor component (Brookfield, 1980).

**Environmental interpretation** The sheet-flood breccias exposed south of Glencaple differ from those at Doweel and Castledykes in the predominance of a single clast type. The clasts are granodiorite, derived from the Criffell intrusion, which is only 2 km to the west. The pluton underlies the high ground west of the Nith and the faulted eastern margin of the pluton is marked by the abrupt change in gradient at the foot of the hill. Palaeocurrent direction, inferred from breccias at Glencaple (Brookfield, 1978), was toward the NE directly away from the granodiorite.

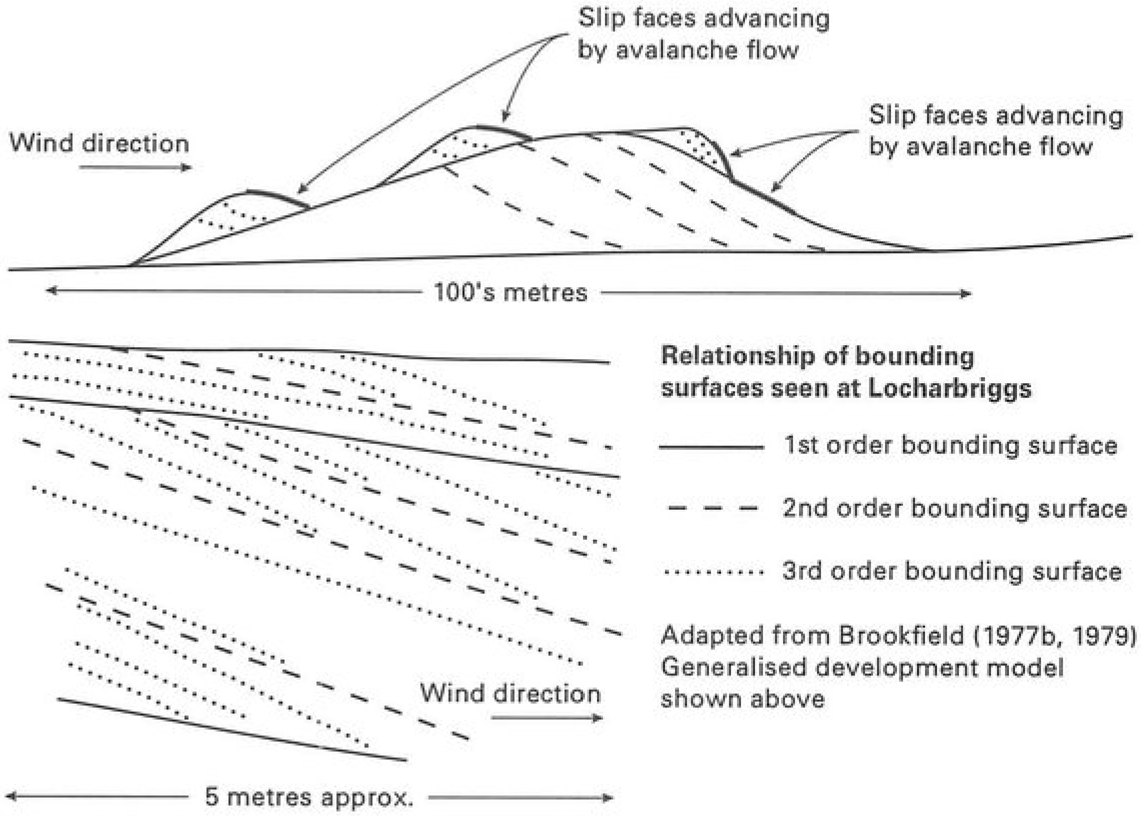
Comparison of clast composition within the Doweel Breccia Formation demonstrates very local derivation from the fault-defined western margin of the Dumfries Basin. Only at the centre of the basin, near the eastern extent of the Doweel Breccia Formation, is there a more varied mixture of clast types. Deposition of alluvial-fan debris near the west side of the Dumfries Basin during the Permian was, therefore, confined within at least two separate alluvial fans (Figure 33) which overlapped only at the centre of the basin.

To return to Dumfries drive north along the B725.

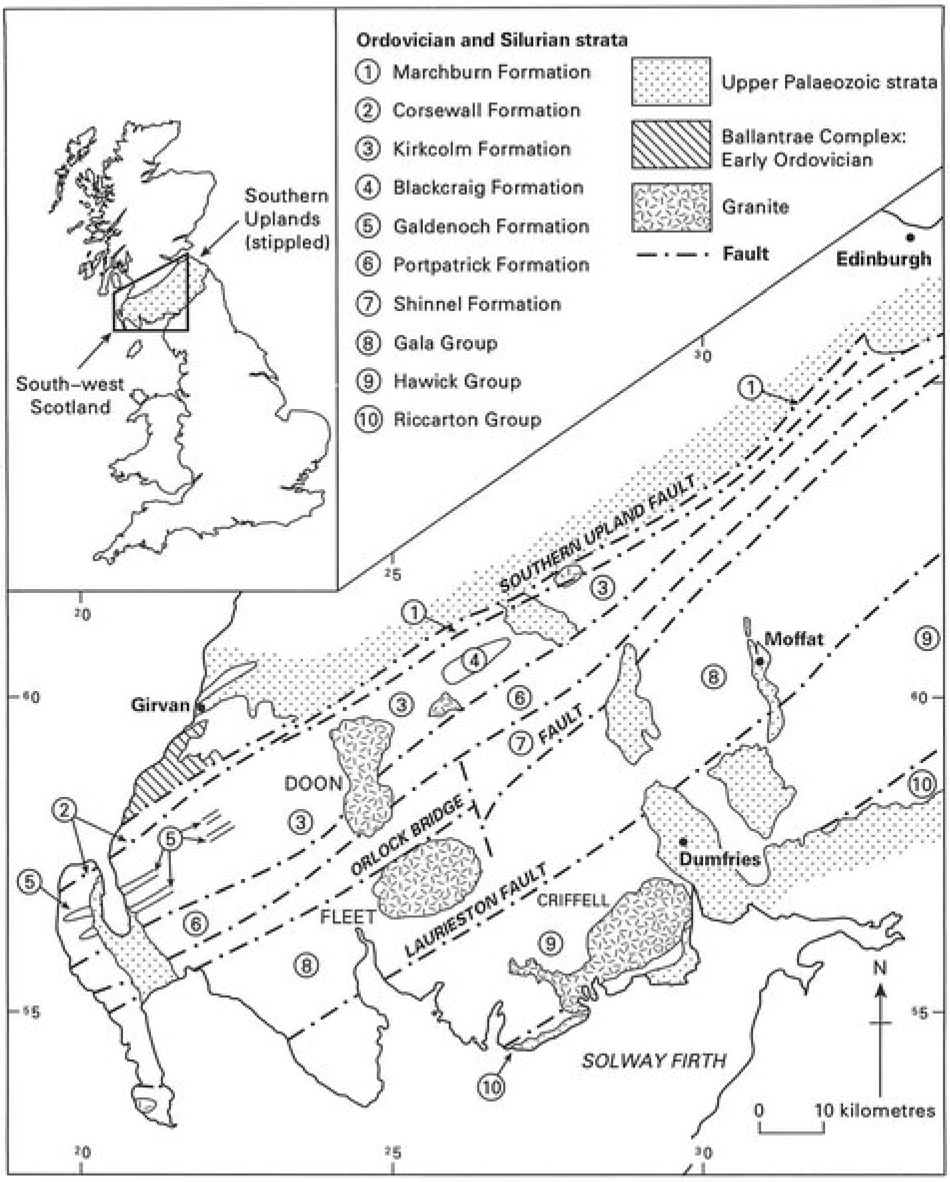
[References](#)



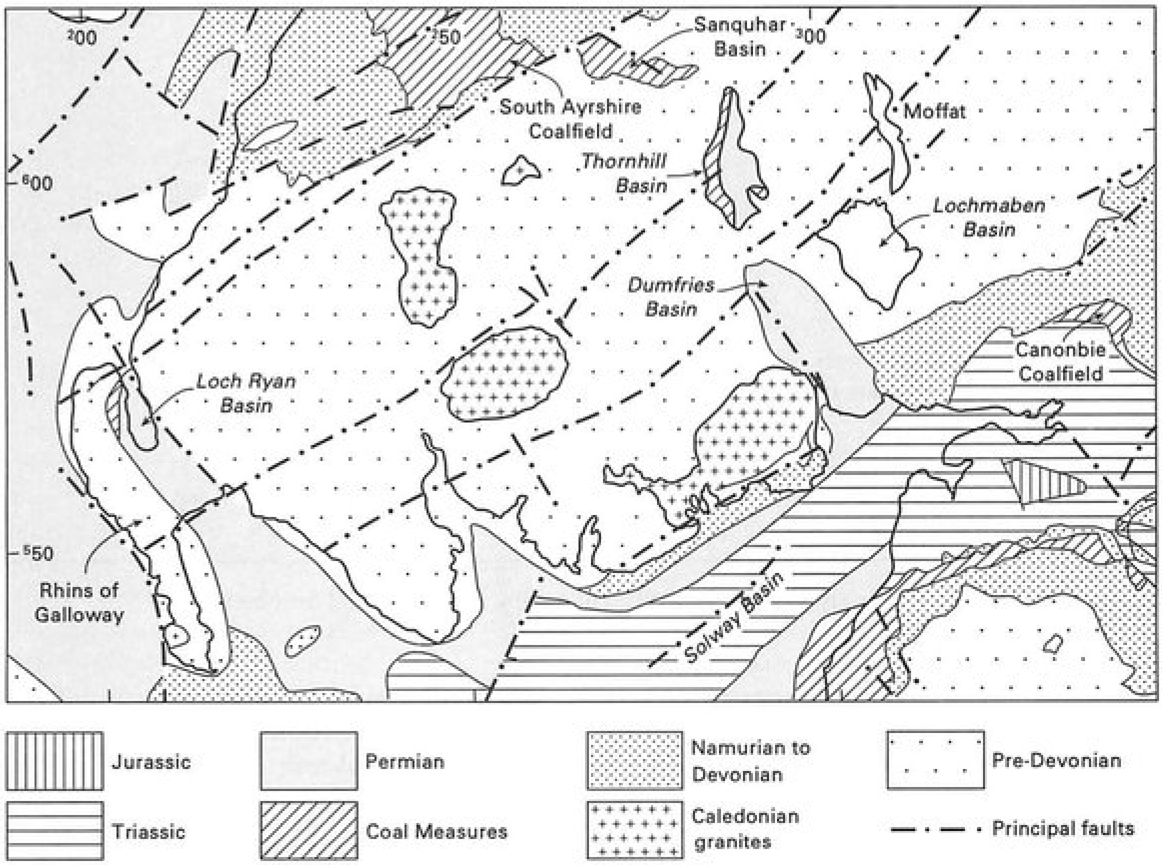

*(Figure 33) Locality map and outline geology for the Dumfries excursion.*




*(Figure 34) Cross-section through an idealised large dune structure illustrating formation of bounding surfaces (not to scale). Adapted from Brookfield (1977b, 1979).*




(Figure 1) Principal features of Lower Palaeozoic geology in south-west Scotland.




*(Figure 8) Upper Palaeozoic geology in south-west Scotland.*