Lossiemouth shore and quarries, Morayshire

[NJ 226 710]–[NJ 231 713]; [NJ 234 706]–[NJ 238 708]

Introduction

The foreshore, raised cliffs, and sandstone quarries in the vicinity of Lossiemouth are the type locality for the Lossiemouth Sandstone Formation. The sediments are dominated by white, fine-grained sandstones, although siltstones and calcrete horizons have been reported. They were deposited by a combination of aeolian and fluvial processes, and have yielded a rich fauna of fossil reptiles that suggest a late Carnian age. The aeolian sandstones are overlain by the Cherty Rock, a highly cemented calcite and silica-rich sediment that has many similarities to present-day siliceous soils of arid and semi-arid areas.

Numerous papers, books and field guides describing the geology of the Lossiemouth area have been published, for example Mackie (1897, 1902a,b), Wallace (1902), Watson and Hickling (1914), Peacock *et al.* (1968), Gillen (1987), Frostick *et al*. (1988), and Naylor *et al.* (1989a). Boreholes have been drilled in the Lossiemouth area (for example Berridge and Ivimey-Cook, 1967). The vertebrate fossils from Lossiemouth have been the subject of many studies, for example, Huxley (1859a,b, 1869), Burkhardt (1900), Walker (1961, 1964), Benton (1983, 1999), Benton and Walker (1985), and Fraser and Benton (1989).

Description

Sedimentology

The best localities in the Lossiemouth area (Figure 3.4) are the quarry west of the School Brae [NJ 231 704], east of the School Brae [NJ 236 707], and the post-glacial raised beaches and associated cliffs to the north (Peacock *et al.,* 1968). These sediments were termed the 'sandstones of Spynie, Lossiemouth and Findrassie' by Peacock *et al.* (1968, pp. 67–70). The dominantly arenaceous sediments at all of these localities are lithologically very similar; the site was independently selected for the GCR for its fossil reptiles, which came mainly from Lossiemouth East Quarry ((Figure 3.5); Benton and Spencer, 1995).

The lowest unit in the sequence exposed at Lossiemouth is approximately 2 m of calcareous siltstones and pebbly sandstones that are yellow, grey or reddish-brown in colour, and are probably attributable to the Burghead Sandstone Formation (Peacock *et al.,* 1968, p. 66). The clasts consist mostly of quartz, with rarer microcline and potassium feldspar, chert, muscovite, and biotite. Small grains of magnetite are scattered across some bedding plane surfaces. Most of the rock is cemented by calcite, although there are patches of siliceous cement. This facies is overlain conformably by the Lossiemouth Sandstone Formation; the contact is exposed in the eastern part of the area (Peacock *et al.,* 1968).

In Lossiemouth East Quarry approximately 9 m of hard, white, well-sorted, commonly well-laminated, fine-grained sandstone has two well-defined sub-vertical joint sets (Figure 3.6); the dominant joint orientation is WNW the subordinate one NNE. Locally the joints are infilled with minerals such as barite and fluorite (Peacock *et al.,* 1968). Farther east, approximately 7.6 m of the Lossiemouth Sandstone Formation is seen 360 m WSW of the old railway station, and is a fine-grained, pinkish-white, massive, and siliceous sandstone. In the middle of the nearby quarry, the sandstone is hard or friable, yellow and grey, and displays excellent examples of large-scale cross-bedding, with individual units 4 to 6 m thick and traceable laterally for over 30 m (Peacock *et al.,* 1968).

The Triassic sediments are also exposed in the post-glacial beaches and cliffs. Here, to the east, the lower part of the section exposes approximately 4.5 m of interbedded yellow and pink sandstones with micaceous siltstones and lenses of quartz pebbles. These are overlain by a pinkish-grey sandstone unit, which is in turn overlain by a hard, grey, 'millet seed' sandstone with well-defined cross-bedding. In the coastal exposures to the west and north of the town, the Lossiemouth Sandstone Formation typically consists of hard, light grey to pinkish-grey, siliceous arenaceous sediments.

Cross-bedding is common, as are joints infilled with quartz, calcite, barite, galena, and pyrite (Peacock *et al.,* 1968).

The upper parts of the Lossiemouth Sandstone Formation are medium- to coarse-grained, becoming increasingly fine-grained upwards, and contain many larger (1–2 mm in diameter) well-rounded clasts of quartz, microcline, quartzite, and chert. This texture was described by Peacock *et al.* (1968, pp. 67, 71) as 'resembling sago pudding'. Close to the top the dominant cement type changes from calcite to silica.

The Lossiemouth Sandstone Formation is succeeded by a chert-rich unit (well-exposed at [NJ 226 707]), first described by Judd (1873), and named the 'Cherty Rock of Stotfield' (Wallace, 1902), the 'Cherty Beds' (Peacock *et al.,* 1968), the 'Cherty Rock' (Gillen, 1987; Naylor *et al.,* 1989a), or the 'Stotfield Cherty Rock' (Frostick *et al.,* 1988). The contact between the two units is irregular but sharp. The Cherty Rock (Figure 3.7) consists typically of about 3 m (maximum thickness, 10 m) of grey or white, arenaceous limestone containing chert clasts, banded chert, and a honeycomb-textured mixture of chert and limestone (Wallace, 1902; Peacock *et al.,* 1968; Naylor *et al.,* 1989a). Thin-section analysis shows that the grains are small pellets (90 to 100 µ,m diameter) composed of concentric micrite layers, arranged in sub-parallel laminae and matrix-supported. The rock is strongly cemented by low-magnesium calcite that occurs as micrite, microspar, and sparry crystals. Ferroan calcite occurs as a later cement, generally infilling tension gashes. Silica cements are also prevalent in the Cherty Rock, and consist of chalcedony, microquartz, semi-opaque crystalline silica, and coarsely crystalline quartz (Naylor *et al.,* 1989a).

Veins and cavities are common throughout this facies, and are infilled by quartz, calcite, pyrite, and galena intergrown with sphalerite. The rare mineral phosgenite has been recorded from the Cherty Rock in the vicinity of Lossiemouth, and is thought to have formed from the interaction of sea water with galena (Starkey, 1988).

Palaeontology

Most of the vertebrate remains recovered from the Lossiemouth area come from the East Quarry, and probably from sediments exposed towards the base of the Lossiemouth Sandstone Formation (Benton and Walker, 1985). The bones may be well-preserved and articulated, although they are normally preserved as soft and friable bone (Walker, 1961), natural moulds (Fraser and Benton, 1989), or are replaced by minerals such as goethite and fluorite (Benton and Spencer, 1995). The assemblage (Benton and Spencer, 1995, Benton, 1999) consists of the procolophonid *Leptopleuron lacertinum,* the sphenodontian *Brachyrhinodon taylori,* the rhynchosaur *Hyperodapedon gordoni,* and the archosaurs *Stagonolepis robertsoni, Ornithosuchus longidens, Erpetosuchus granti, Scleromochlus taylori,* and *Saltopus elginensis.* The site was also selected for the GCR for its fossil reptile fauna (Benton and Spencer, 1995)

Interpretation

The sediments at Lossiemouth were deposited in terrestrial environments under both fluvial and aeolian conditions, in a half-graben associated with the Great Glen Fault (Frostick *et al.,* 1988).

The poorly sorted, yellowish, grey, and reddish-brown sandstones and siltstones, with scattered, angular quartz clasts, of the Burghead Sandstone Formation are indicative of deposition by rivers. In some localities in the Elgin district, ventifacts are present (Peacock *et al.,* 1968), suggesting that aeolian processes were important. The small-scale cross-bedding and associated silty laminae, desiccation cracks and rare mud-pellet conglomerates imply that the rivers were located on floodplains that experienced semi-arid to arid climatic conditions (Peacock *et al.,* 1968; Williams, 1973).

The overlying Lossiemouth Sandstone Formation is characteristically well-sorted, well-cemented and preserves large-scale cross-bedding, features that are typical of aeolian sedimentation (Shotton, 1956; Peacock *et al.,* 1968). The formation consists of sand reworked from the Burghead Sandstone Formation and deposited from large dunes as they migrated across floodplains. The directions of dip of the dune cross-bedding indicate that the dominant palaeowind direction was from the south (Williams, 1973; Benton, 1983). The reptile fossils are known only from the aeolian sandstones. The animals lived in and around the dunefields, and probably moved to vegetated floodplain and interdune areas for food (Benton, 1983). The 'sago pudding' sandstone has features, such as large, angular clasts and many heavy minerals that are consistent with transport by water (Peacock *et al.,* 1968).

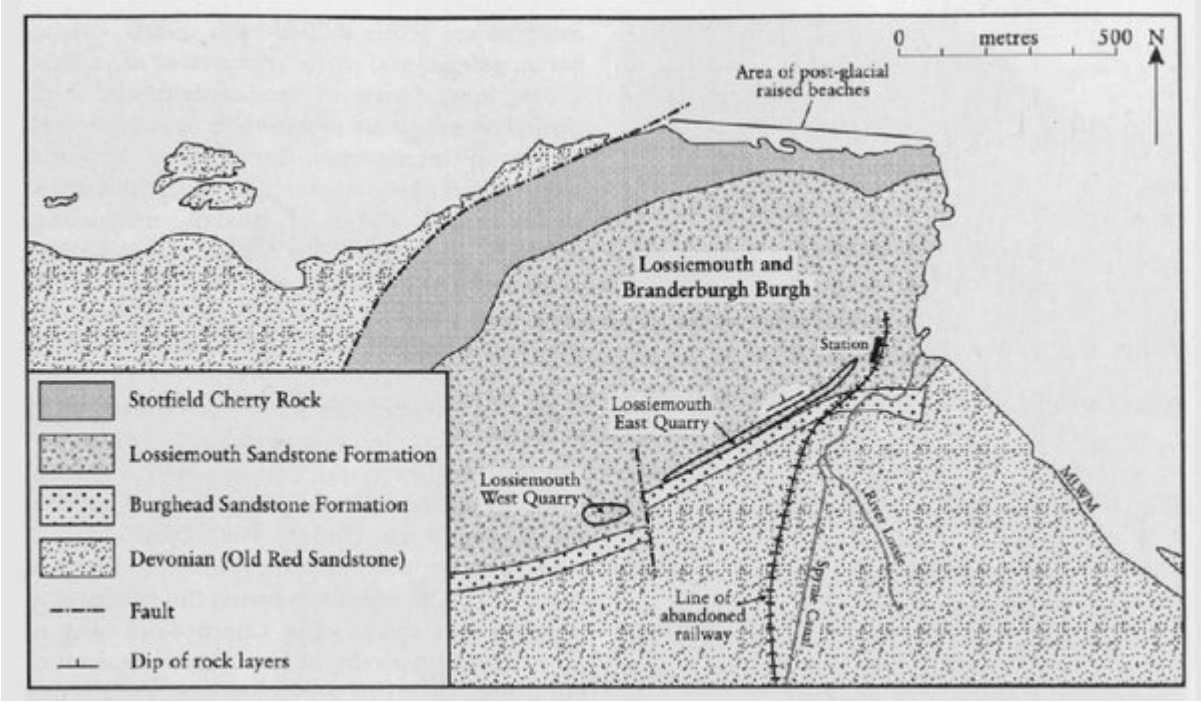
The overlying Cherty Rock shows textures similar to those of modern and ancient calcrete and silcrete soils, such as the concentrically laminated pellets that resemble glaebules seen in silcretes (Naylor *et al.,* 1989a). The presence of silica in calcrete profiles is common (see, for example, Goudie, 1973). It is thought that the silica in the Cherty Rock is a replacement of calcite precipitated as soil carbonate or calcrete, followed by repeated cycles of solution and reprecipitation (Naylor *et al.,* 1989a). The calcrete and silcrete palaeosol horizons support the hypothesis that the region experienced a semiarid or arid climatic regime during the Triassic Period. The Cherty Rock has been recorded in numerous boreholes in the Moray Firth, and is a useful marker horizon for correlation (Frostick *et al.,* 1988);it can be correlated with a cherry limestone that outcrops in the vicinity of Dunrobin (Phemister, 1960; Gillen, 1987; Andrews *et al.,* 1990; Cameron, 1993) on the northern side of the Moray Firth.

Dating the Lossiemouth Sandstone Formation is difficult. The vertebrate assemblage suggests a late Carnian (Iiwalian Substage) age, by comparison with faunas from North and South America (Benton, 1994). This is equivalent to the Adamanian land vertebrate faunachron (Lucas and Hunt, 1993) and the *Rutiodon* Assemblage Zone (Lucas, 1998). The Cherty Rock is assigned a Rhaetian age, based on its occurrence above the Carnian Lossiemouth Sandstone Formation, and below Lower Jurassic shales, which contain Sinemurian ammonites (Peacock *et al.,* 1968).

Conclusions

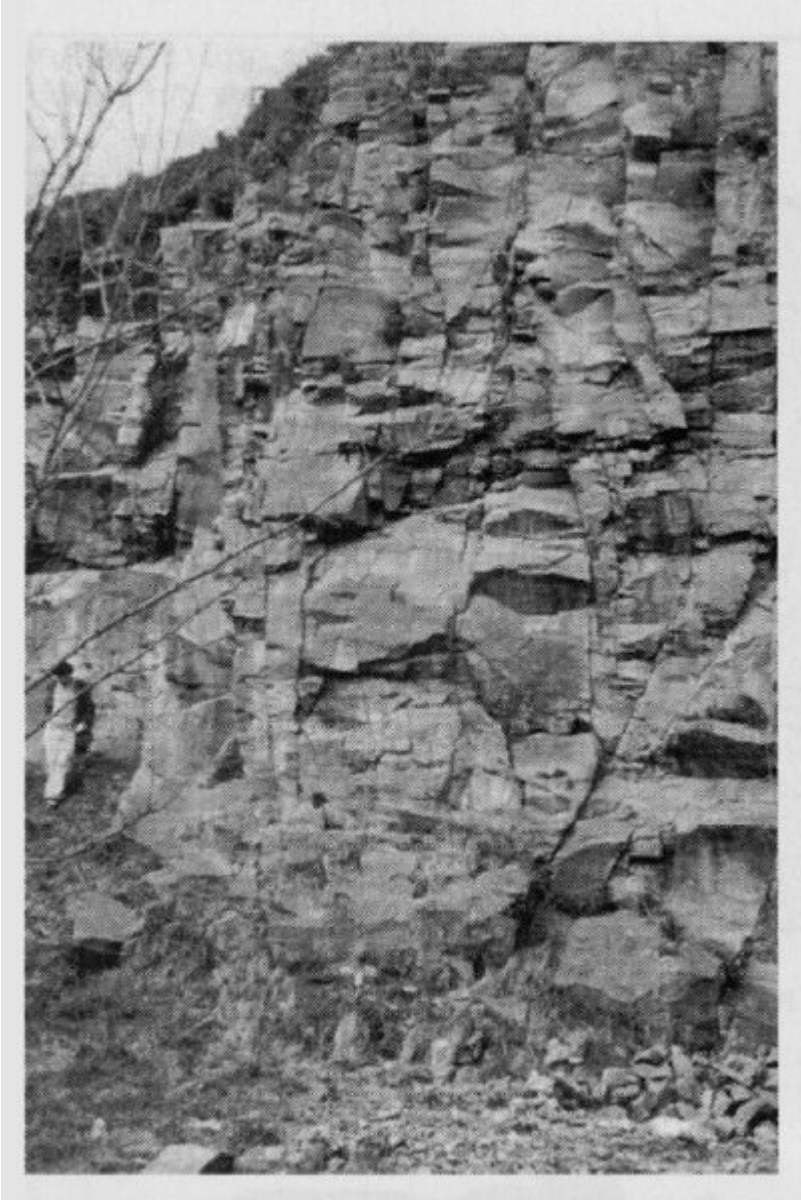
Lossiemouth is the type locality of the Lossiemouth Sandstone Formation. The dominantly arenaceous rocks were deposited under terrestrial conditions, and include sediments of aeolian and fluvial origin. The Lossiemouth Sandstone Formation is internationally famous as a source of Triassic reptiles. The overlying Cherty Rock has been interpreted as a fossil soil horizon with a complex geological history.

References



(Figure 3.4) Occurrence of the Lossiemouth Sandstone Formation in its type location, in Lossiemouth, and on the foreshore north of the town.

(Figure 3.5) Lossiemouth East Quarry, showing water-laid Burghead Sandstone Formation at the base, and large aeolian cross-bedded sandstone sets in the Lossiemouth Sandstone Formation above. The face is about 9 m high. (Photo: C. MacFadyen.)



(Figure 3.6) Lossiemouth East Quarry: view of heavily jointed, dune cross-bedded sandstones at the eastern end of the site. (Photo: M. J. Benton.)

(Figure 3.7) The Cherty Rock on the foreshore north of Lossiemouth, a close-up showing its fractured nature. (Photo: C. MacFadyen.)