AN OLD SHORE-LINE.

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On the coast of East Sutherland, between Golspie and Helmsdale, occurs a narrow strip of Mesozoic sediments separated from the Old Red Sandstone, crystalline schists and granite of the interior by a powerful fracture-line known as the Ord Fault. This coastal strip attains a maximum width of nearly three miles westwards from Brora but when followed north-eastwards gradually diminishes in width until at Dun Glas, near the Ord of Caithness, the boundary fault passes out to sea. The sub-divisions of the Mesozoic rocks represented in East Sutherland are:—

KIMMERIDGIAN—Shales, calcareous sandstones and "Boulder Beds."
CORALLIAN—Sandstones, limestones and shales.
OXFORDIAN—Sandstones, clays and shales,
LOWER OOLITE, ESTUARINE BEDS—Shales and sandstones etc., including coal worked at Brora.
LOWER LIAS—Clays and thin limestones, and sandstones.
(?) RHAETIC—Grits and conglomerates.
TRIAS—Cherty rock and marls resting on calcareous sandstones.

The subject of this address was the series of deposits referred to in the above table as "Boulder Beds." These boulder-beds or breccias form the most outstanding feature in the Kimmeridgian strata here. They consist of blocks or boulders of sandstone and flags embedded in a matrix of black shale, thin-bedded shelly limestone or calcareous sandstone. The matrix contains characteristic fossils and is definitely of the same geological age as the Kimmeridgian rocks among which the boulder-beds occur. The included boulders on the other hand belong just as clearly to a much

earlier period; they yield comparatively few fossils but at certain localities fish-remains have been obtained which show them to be of Middle Old Red Sandstone age. The Jurassic and Old Red Sandstone formations are separated by a very long interval of time and this gap in the geological record in East Sutherland is filled in elsewhere in Britain by the thick deposits of the Carboniferous and Permian formations. We can estimate the time-interval roughly in another way and say that it represents the transition from the primitive plants and fishes of Old Red Sandstone times to the cycads and giant reptiles of the Jurassic.

The boulder-beds are found along the coast between Kintradwell and Dun Glas and are best seen between tide-marks at Port Gower and again to the north at Helmsdale. The main features of the deposits may be shortly summarised:—

(1) The matrix or material in which the boulders are embedded represents shallow-water sediments laid down in the Jurassic (Kimmeridgian) sea.

(2) The boulders themselves belong lithologically and faunally to the Middle Old Red Sandstone.

(3) The boulders are as a rule angular and lie orientated at all angles.

(4) They vary in size within wide limits, from small fragments up to 31, 40 or even 90 feet long and the larger ones include many different types of Old Red Sandstone rock.

(5) Frequently they can be seen resting on fossiliferous Jurassic mudstones or shales, the bedding of which is often bent or waved at the points of contact.

A number of explanations have from time to time been put forward to account for these peculiar boulder-beds. They have been ascribed, for example, to the result of

mechanical deformation following on the intrusion of the Ord Granite, to torrential river-action, to the work of ice, to a cliff-talus or scree, or to the action of earthquakes along a submarine bank. The Ord Granite, however, is definitely of pre-Old Red Sandstone age, while it seems unlikely that river-floods could carry such large masses of rock (consisting of mudstones, friable sandstones, and sandy limestones) and deposit them unbroken and piled up where they now lie. Glacial action again appears to be ruled out for the following reasons:—

(1) The boulders are unstriated and angular and would have shown a greater range of lithological types, if due to carriage by ice.

(2) There is no evidence of glacial conditions in late Jurassic times; the fauna and flora indeed indicate exactly the reverse.

The most probable explanation is that which assigns the boulder-beds to marine erosion along a line of cliffs. The cliffs were formed of Middle Old Red Sandstone rocks and the sea which washed their base was the Kimmeridgian sea of late Jurassic times. Undermining of the cliffs brought down large masses of rock, and the impact of these on the sediments gathering in the sea can still be traced in the waved and contorted lamination of the Kimmeridgian shales. This cliff-talus explanation accounts for the varied size of the boulders, their general angular character, and the fact that their bedding planes are sometimes vertical, sometimes horizontal and sometimes oblique. It explains also the fact that at any one locality the boulders are of the same general lithological character (sandstones, flagstones, etc.), and show no greater range in type than might be expected in a vertical cliff of Old Red Sandstone strata.

We have thus preserved to us in these Kimmeridgian boulder-beds a piece of fossil scenery. They show us that in late Jurassic times there was a range of sea cliffs here

composed of Middle Old Red Sandstone rocks. Strangely enough there exists at the present day along the Caithness coast cliffs showing walls of horizontally-bedded Middle Old Red Sandstone strata at one place hollowed out into caves, at another interrupted by narrow inlets or goes. Here and there pinnacles of rock have been isolated by the sea to form stacks. The old Jurassic cliffs, whose debris has gone to form the boulder-beds of East Sutherland, may well have shown a somewhat similar scenery. One of the largest boulders preserved measures roughly 190 feet in length and 90 feet in breadth; it is composed of sandstone, grey, green and red mudstones and bands of limestone and lies now pointing seaward with its bedding vertical. May this gigantic boulder not represent a part of an undercut stack that has toppled over on the floor of the old Kimmeridgian sea?

Readers who desire more information regarding the geology of East Sutherlandshire should consult the following:—One-inch Geological Map of Scotland, Sheet 103, Colour-printed edition, 1925.

'Geology of the Country around Golspie' Mem. Geol. Surv. 1925.

'Excursion to East Sutherland' (1929), Proc. Geol. Assoc. (vol. XLI, 1930, pp. 63-86).