

ART. XXXV.—*The Fossil Plains of North Otago.**

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Plates XXX, XXXI.

A FOSSIL is a thing "dug up," and to the palaeontologist the term "fossil" indicates something buried a very long time ago and dug up very recently. By the term *fossil plain*, therefore, may be understood a plain which, after coming into existence as a plain of erosion, has been buried by sediment and long afterwards re-exposed by renewed erosion. The sloping plateau surfaces to which the name is here applied are the most striking features in the character-profiles of North Otago.†

As a rule, in that district a fossil plain forms one side of the unsymmetrical valley developed in a fault-angle. On the one side is a fault-scarp more or less dissected; and on the other is the tilted surface of the next earth-block, from which the weak cover has been stripped, revealing the planed surface of the undermass.

As is more fully explained in another paper,‡ the dissection of the surfaces, though they are inclined, is generally shallow, because of the close spacing of numerous consequent§ streams, which, combined with the small rainfall, gives such streams steeply sloping profiles even when fully graded. Only a few larger streams trench deeply. Thus the fossil plain, once stripped, is a stable form under the climatic conditions prevailing in North Otago, and this accounts for its common occurrence.

THE SHAG VALLEY FAULT-ANGLE.

The fault-angle depression known as the Shag Valley is an excellent example of the type. This depression is really a branch of the Central Otago depression-system, and it connects that system with the greatest of all depressions—the Pacific Ocean. The divide between the head of the south-eastward-flowing Shag River and the streams flowing westward to the Maniototo Plain is situated in an area of mature topography developed on covering strata strengthened by the presence of abundant volcanic rock. There is thus, as it were, an artificial separation of the Shag Valley depression from the Maniototo depression, the most easterly member of the Central Otago system proper, which would be much less prominent but for this local strengthening of the overmass.

The fault-scarp of the Kakanui Range, which forms the north-eastern boundary of the Maniototo depression, continues south-eastward along the front of that portion of the highland block termed the Horse Range, and thus forms the boundary of the Shag Valley depression also, being here opposed by one of the most perfect sloping plateaux in Otago—a fossil plain (see fig 1, and Plate XXX, fig. 1)—which descends at a low angle north-eastward and eastward, passing, towards the sea and in the seaward portion

* The subject-matter of this article formed part of a paper on "Block Mountains in New Zealand," read before the Wellington Philosophical Society, part of which has been published in the *American Journal of Science* (vol. 44, 1917, pp. 249-93).

† C. A. COTTON, *The Structure and Later Geological History of New Zealand*, *Geol. Mag.*, dec. 6, vol. 3, 1916, pp. 243-49, 314-20 (see p. 315).

‡ *Loc. cit.* (1917), pp. 256-58.

§ More strictly termed "*superposed consequent*" at the present stage of their history.

of the depression, under marine covering strata, while on its surface are a number of remnants of cover, the largest of which are composed mainly of volcanic rock. Some of these which now form conical hills on the seaward part of the sloping plateau are probably necks.

The Shag River does not follow the fault-angle closely, but is in places superposed on the sloping plateau of the south-western side at a distance of several miles from the axis of the depression.

As the fault-scarp of the Kakanui-Horse Range is followed inland (north-westward), remnants of the covering strata are found at its immediate base inclined towards the scarp at the same angle as the stripped floor farther back. Some of these remnants, moreover, may be seen to rest upon a floor of schist (of which rock the whole of the sloping plateau of the south-western side is also composed), but the rock of the fault-scarp at the foot of which they lie is greywacke. Thus we have here not only a clear demonstration of the tectonic nature of the depression, but also an example of the general relation between the presumably older schist and the presumably younger greywacke along the border of the northern highland of Otago—namely, that the older rock is on the downthrow side of the fault-junction, indicating a reversal of the sense of movement, or, rather, that the youngest faults, where they have followed the lines of older dislocations, have done so merely because here lay lines of crustal weakness, and not because the latest movements were a continuation of those of a former period.

The excavation of the overmass in the lowest portion of the depression has followed a regional uplift much later than the movements by which the depression was formed, and the effects of this are here important owing to the fact that the course of the Shag River to the sea is a short one. Composite topography, though traceable, is not sufficiently prominent to vitiate the general account of the relief given above, which has, for simplicity, been stated as though the whole feature had been developed in a single cycle.

For the explanation of one curious detail of the mature fault-scarp of the Horse Range, forming the north-eastern side of the depression, the two-cycle origin must be borne in mind. One of the streams of the fault-scarp is exceptionally large, heading far back in the range, and this stream, instead of debouching cleanly into the fault-angle, turns sharply to the left while yet within the range-front, and flows for a mile or two parallel with the scarp and separated from the fault-angle depression by a long narrow spur of the undermass. It would seem that this stream when it entered the depression at a higher level had built forward a large fan at the base of the already mature fault-scarp, and that when rejuvenation occurred it had been flowing down that radius of the fan which lay closest to the scarp, so that when it cut downward it became superposed on the undermass of the range-front.*

THE OAMARU DISTRICT

The fault-scarp which forms the north-eastern side of the Shag Valley dwindles in height towards the south-east. The block which it bounds (Kakanui-Horse Range block) is strongly tilted to the east, and its surface on that side is now a fossil plain sloping eastward and north-eastward towards the sea, and dipping under and forming the floor of the marine Tertiary rocks of the Oamaru district

* *Loc cit* (1917), see fig. 9.

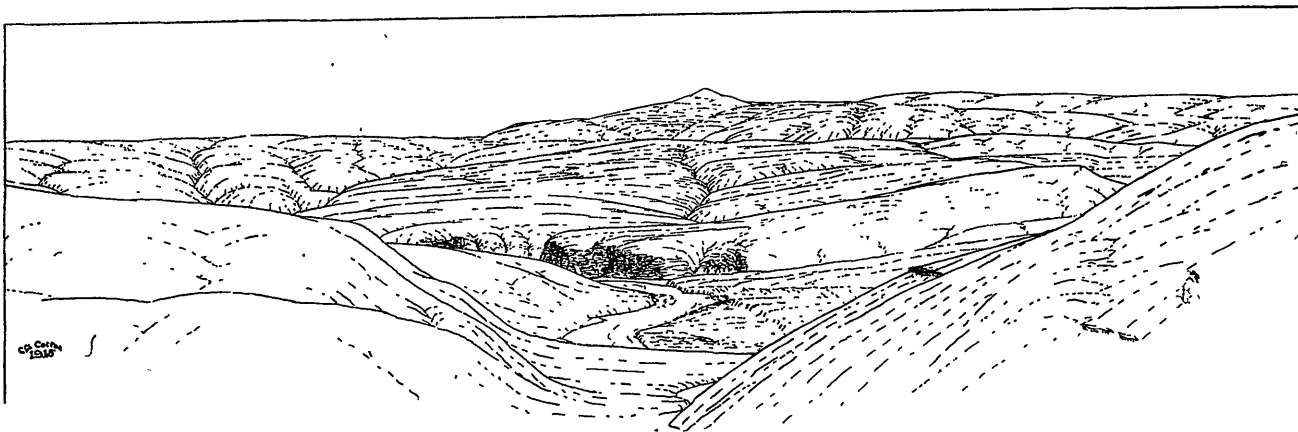


FIG. 1.—Fossil plain descending to the Shag Valley from the south-west. A residual hill capped by lava is on the distant sky-line. Subdued hills of the covering strata preserved in the fault-angle are seen in the foreground, and the Shag River is in the centre. The undermass is schist

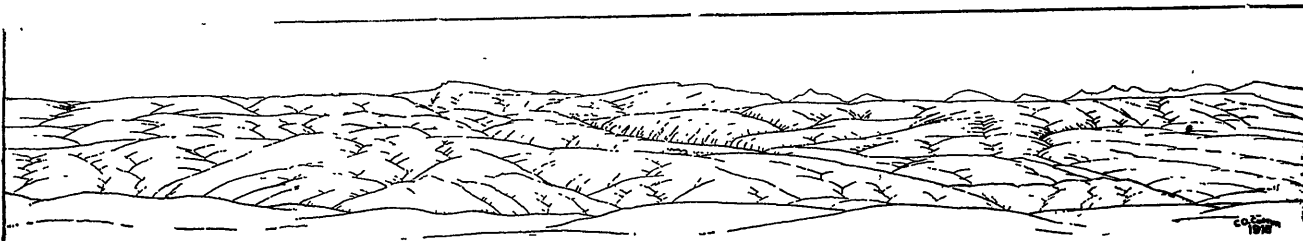


FIG. 2.—Fossil-plain surface of the Kakanui-Horse Range block descending north-eastward to the Oamaru district, and covered by marine strata in the foreground.

This fossil plain is strikingly similar to that of the Shag Valley fault-angle. Obviously it had a similar origin, and it is practically certain that the two were continuous prior to the Kaikoura orogenic movements (though at that time deeply buried under covering strata).

The surface is somewhat undulating, being "folded" to some extent like the adjacent covering strata. This has introduced slight irregularities in the pattern of the consequent drainage, but the majority of the streams run north-eastward in the direction of the general slope.

While the dissection is in general shallow, some master streams—*e.g.*, the Waianakarua (Plate XXXI)—are deeply incised in steep-walled gorges, which necessarily become deeper as they are followed back from the debouchures, the gradients of the streams being decidedly less steep than the slope of the fossil plain.

THE WAITAKI GRABEN.

The Waitaki River is consequent on the Kaikoura deformation. The middle and lower Waitaki follow a straight course in an east-south-east direction through a somewhat complex graben between the highland blocks of North Otago and those of South Canterbury. Its tributary the Hakataramea enters from a great northerly-trending fault-angle depression.

In the Waitaki graben there are several small blocks of great interest as examples of tectonic forms. One small tilted block just behind Kurow exhibits an almost perfectly preserved back-slope and even crest-line (see fig. 3).

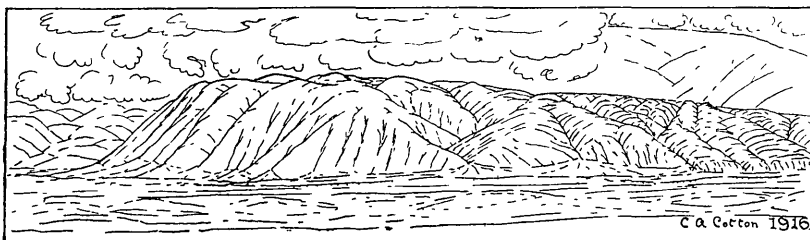


FIG. 3.—Small tilted block in the Waitaki Valley graben. View looking south-westward across the bed of the Waitaki River. The height of the scarp at the eastern end is about 1,000 ft. At the western end a glimpse is caught of the crest-line of the northern highland of Otago.

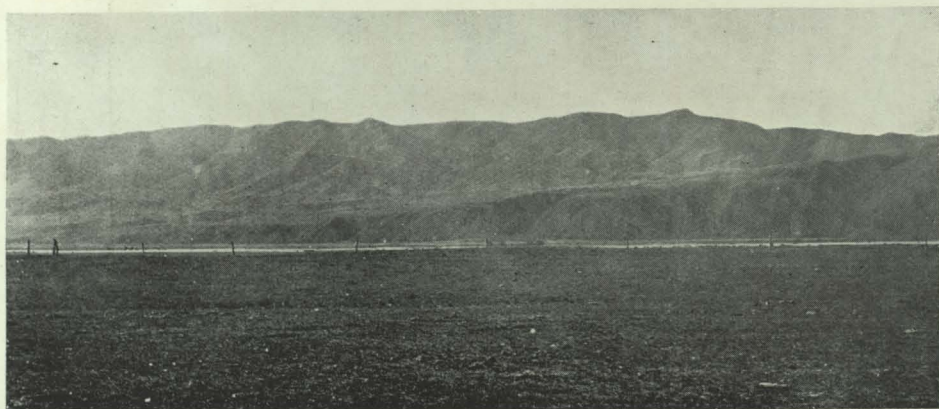
Another striking feature is a splinter from the northern fault-scarp of the graben just opposite Duntroon (Plate XXX, fig. 2). The fossil plain or stripped surface of the greywacke undermass, which is similar to that of the back-slope of the Hunter's Hills,* forms a plateau considerably over 1,000 ft. above the level of the valley-floor, and a strip of it descends in a westerly direction along the splinter, coming right down to the level of the low terraces bordering the river. While the cover has been removed, the fossil plain is almost untouched by erosion. The fault-scarp at the back of the splinter is well preserved; that in the front has been sharpened by the river.

* C. A. COTTON, *loc. cit.* (1916), fig. 2, p. 316.



[C. A. Cotton, photo.]

FIG. 1.—Fossil plain of the south-western side of the Shag Valley, sloping down towards Palmerston.



[C. A. Cotton, photo.]

FIG. 2.—A splinter from the fault-scarp of the northern side of the Waitaki graben. View looking northward from Duntroon.



[C. A. Cotton, photo.]

A portion of the fossil plain shown in text-fig. 2, showing the gorge of the Waianakarua.