14. An Unusual Type of Deformation in a Basic Sill

By

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During a trip to Labrador the summer of 1949, I found an unusual type of jointing in one of the numerous basic sills around Aillik Bay (Fig. 1). The discovery was made late one evening the day before we moved camp, and there was no time for detailed study of the place, and so the information presented here is very sketchy. However, the case is so unique that it may be worth while saving it from oblivion, particularly because the outcrop may now be destroyed by defence construction work on the place.

After my visit, the region was mapped by the British Newfoundland Corporation, in connection with prospecting for uranium. The outcrop does not seem to have been noticed by the geologists of the company. The general geology of the Aillik–Makkovik area has most recently been described by BEVAN (1958) The petrography of the dyke rocks was briefly described by the present author (1954).

The bedrock around Aillik Bay consists mainly of quartzite with some thin layers of shaly material and limestone. These sediments are intruded by granite and basic igneous rocks. West of the bay the sediments are only gently folded, and show good primary bedding, ripple marks, mudcracks, etc. On the east side the folding has been stronger, and the rocks often show a good schistosity with steep dipping schistosity planes.

Later than the deformation, the sedimentary series was traversed by a great number of sills and dykes composed of granite, quartzmonzonite, rhyolite, diabase, and lamprophyres of different kinds. The aspects of the major sills in the landscape is shown by Fig. 2.

It can be mentioned that two big diabase dykes running across the bay seem to be slightly displaced, indicating a horizontal thrust.

The outcrop with the joints is situated on the east shore of the bay about two miles from Cape Makkovik, 30 feet from the shore. The horizontal upper surface of the sill is exposed over an area of about 150 square feet. The contact with the underlying quartzite is exposed in one side of the outcrop. The thickness of the sill is between two and three feet. It consists of a fine grained, dark greenish gray, very homogeneous basic rock of a type which forms extensive almost horizontal sheet like bodies in the region. Many can be followed for several miles.

Fig. 1. Map showing the location of Aillik.

The sill is cut by two systems of vertical joints in about 20° angle to each other. Each main joint is composed of small screw shaped diagonal joints producing on the surface of the sill, a pattern resembling a twisted rope (Fig. 3). There is a perfect cleavage along the joints, giving rise to the parting of elongated rods of rock. The rods show in cross section the characteristic sigmoid shape with sharp, drawn out edges (Figs. 3–4). On the surface of the rods there is a faint striation indicating a movement perpendicular to its elongation, obviously

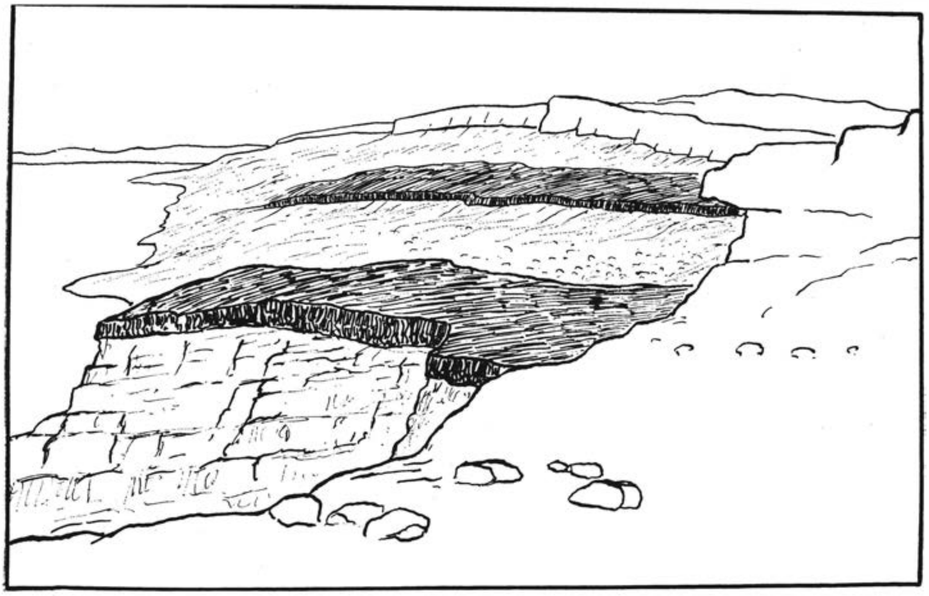

Fig. 2. Lamprophyric sill in quartzite of the type in which the joint system occurs. This sill is on the west shore of the bay. The joint locality is on the east shore in a sill which may be the continuation of the same.

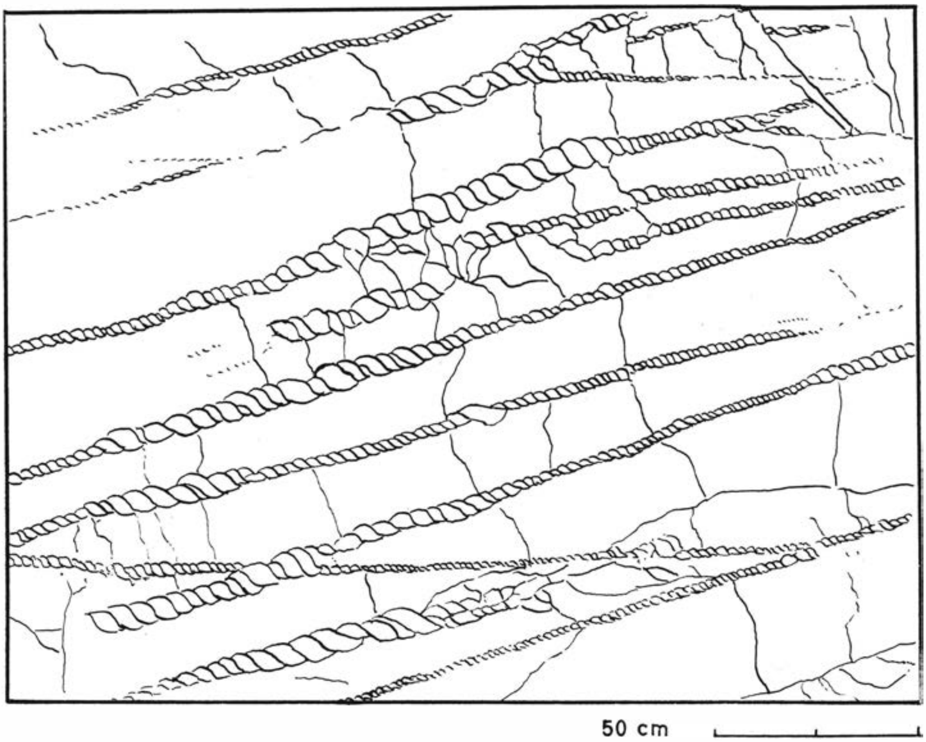

Fig. 3. The joint pattern on the surface of the sill. Observe two directions of principal joints and a set of tension joints about 90° to the principal joints.

produced by a slip movement. Traces of shearing are generally seen in the middle of it (Fig. 5c). There is no cleavage along this shear plane.

Figure 4, drawn after a photograph, shows the general picture of the joint system. The thickness of the complex joints varies from less than an inch to about three inches. The pattern is the same regardless of the size. The two joint systems seem not to interfere with each other. The portion of the rock between the two joints looks as if it had been cut by a rocksaw. The surface shows a ripplemark like aspect (Fig. 4).

The mineralogical composition of the rock is simple. It consists of about 20 percent of small pale-green prismatic crystals of hornblende, and 75 percent of plagioclase with fairly strong zonal structure (andesine). The more An-rich centre of the grains is saussuritized. Alkali feldspar is present only in very small quantities. The accessory minerals are magnetite, sphene, and apatite, occurring only in small quantities. Epidote is fairly common as a deuteric alteration product. The composition is somewhat similar to a diorite and a diabase. The rock has been classified as a vogesite because of the dominance of hornblende and the association with lamprophyric dyke rocks.

From the point of view of the present discussion, the most important feature

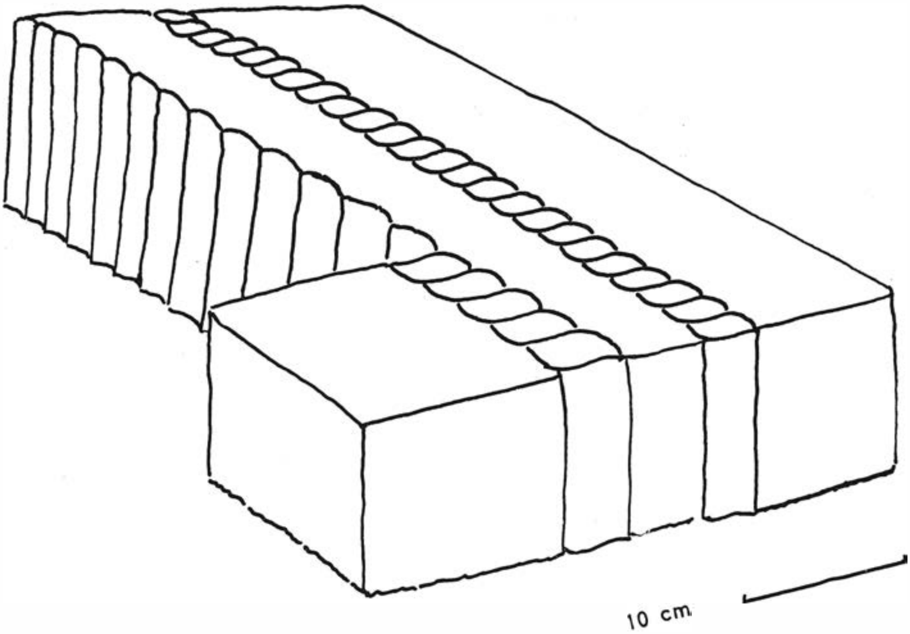

Fig. 4. The joint system, in three dimensions showing the parting in long slabs with sigmoid cross-section (compare the photographs Pl. I).

of the rock is the complete lack of mechanical deformation in its texture. The slight parallel arrangement of the hornblende crystals is undoubtedly a primary flow structure. The force that produced the jointing has left no visible trace in the rock.

The joint pattern therefore must be a shear tension phenomenon, formed when the rock was completely solid. It is not formed by plastic deformation. The stress conditions responsible for such a shearing are rather complicated and the following discussion of the origin of the joints is only tentative.

We have to explain the following facts:

1. The composite joints.
2. The shape of the cross joints.
3. The pointed edges of the segments of parting, and the movement that produced the striations on their mantle surface.
4. The shear joints (Fig. 5 *C*) cutting each segment parallel with the axes.
5. The tendency to form arcuate fissures on both sides of the main joint system (Fig. 3).
6. The existence of two systems of composite joints at an oblique angle to each other.

I think we can assume that the composite joints as such originally developed as so called feather joints produced by couples of forces (f_1) in the way schematically shown in Figure 5 *A*. (The displacement is exaggerated in the figure.) Simple feather jointing can be seen in the continuation of some of the composite joints. The sigmoid shape of the diagonal joints seems to be the result of tor-

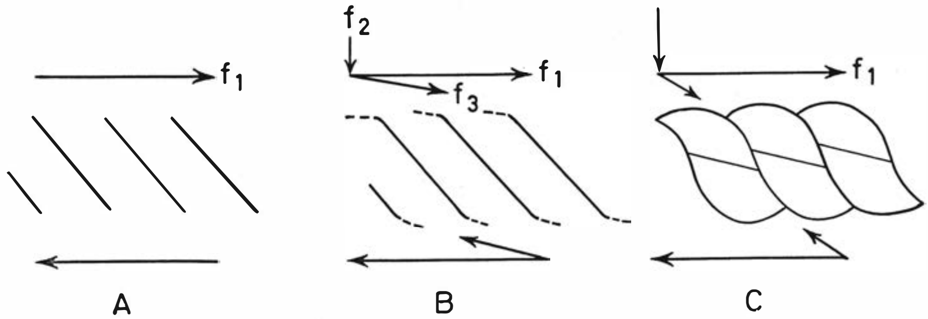

Fig. 5. Scheme of the formation of the sigmoid jointing. A. Formation of feather-joints caused by the couple of forces f_1. B. The tranversal force f_2 causing a deviation of the joint direction. C. Formation of diagonal jointing and shear jointing parallel to the principal joint direction.

sional stress produced by an interaction of several forces. The existence of a set of transversal tension joints suggests that there was one force acting perpendicular to the principal joint system. A gradual increase of this pressure (f_2) during the deformation caused a deviation of the original tensile force produced by the force couple f_1 to f_3 (Fig. 5*B*), and at the same time the pressure of the solid siderock on the deformed portion becomes stronger. Shearing will take place along the veins (*B*), and a new tension joint system cutting diagonally through the rockslabs (*C*) formed by the first feather joints and the later shear joints. It is interesting that the angle between the both systems is about 45°.

Striation along the rockslabs shows that a certain movement of rotational type took place during the deformation and, this movement is responsible for the knife-sharp edges of the slabs.

This attempt to explain the rather complicated mechanism at which the sigmoid jointing formed is very incomplete and only tentative. I hope that somebody more familiar with stress mechanics in rocks will be able to find a more satisfactory solution of the problem, and also to hear if similar structures have been observed elsewhere.

The tectonics of the Aillik area is not known well enough to relate the jointing described to the structure of the surrounding areas. The fact that this kind of jointing, to my knowledge, has never before been described indicates that conditions must have been exceptional. It is, however, safe to assume that we have here a deformation in connection with horizontal thrust movement.

It can be mentioned that geometrically similar deformation patterns are fairly common in connection with plastic deformation. As an example we can take the lens gneisses described by WEGMANN in his paper (1939) about the migmatites of southwest Greenland. This gneiss has pegmatite inclusions arranged in a feather position similar to the jointing described in this paper, and with exactly the same screw form. Here, however, the tension-joints have been compressed and opened by a force perpendicular to the joint, thus forming channels for the pegmatitic material. Screw formed feather joints in pegmatitic material are not too rare in migmatites.

Postscript

After this paper was sent to the editor I received a study by GILBERT WILSON: "About the Tectonics of the Great Ice Cham, Filchner Ice Shelf, Antarctic" describing a structure which is very closely related to the same discussed by me. This is a most interesting example of similar structures formed in ice and rock.

References

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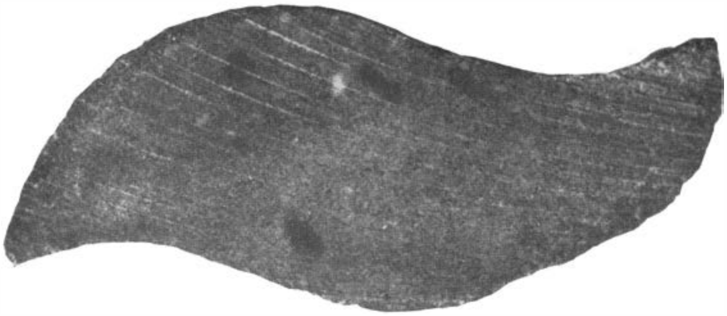
Plate I

a. Cross-section through joint slab. × 1 1/3. b. Joint slabs showing striation vertical to the direction of elongation produced by slip movements. c. The rippled surface of the rock on both sides of the joint system.

Plate I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b
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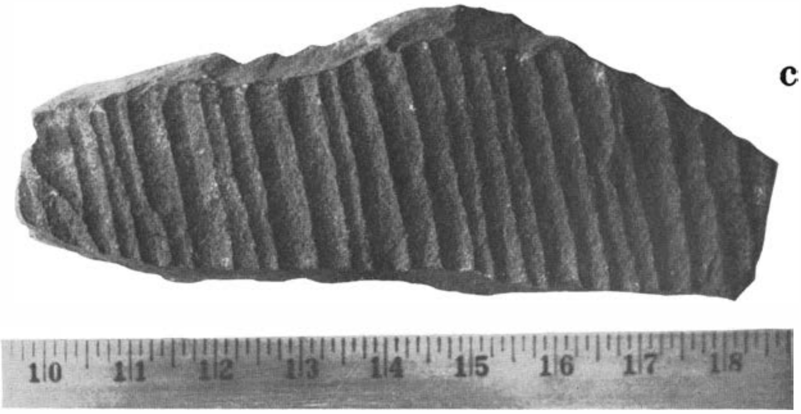
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