Paths and Sequence of Intrusion of Alkaline Rocks on Turja Peninsula

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Abstract

The Turja Peninsula consists of porphyritic granite overlain by sandstone, cut by numerous dikes and veins of varying composition, form, and orientation. The relative ages of the dikes and veins has been established by their mutual intersections, and correlation of these with compositions of the rocks demonstrates the existense of three periods of igneous activity. The dikes and veins of the first period strike predominantly NNE and dip ESE. Most of those of the second period strike E-W and dip N, but those of a subordinate group strike NNE and dip ESE. Those of the third period strike predominantly N-S and dip E. The first and third periods are characterized by fine grained rocks resembling effusives, the second by coarse grained typically intrusive rocks and intense metasomatism that altered both dikes and veins and the wall rocks. The difference in texture of rocks formed at the same depth horizon is attributed to a difference in temperature of the wall rocks and the rate of rise of the magma through them.

The western and southern coasts of the Turja Peninsula, a peninsula projecting into the Kandalaksk Bay of the White Sea, consist of rapakivi-like porphyritic granites, overlain in the southern part by sandstones that change locally into quartzite.

A large fault (part of the northeastern side of the Kandalaksk rift) crosses the southern part of the peninsula. Glacial erosion has exposed numerous dikes, veins, and veinlets that cut both the granite and the sandstones, and extend laterally into them along lamination planes and joints. Only at three of the many exposures is the mode of occurrence of the igneous rock uncertain. Two of these are in granite, and appear to be small stocks or volcanic necks. One is oval in ground plan, with diameters of 80 × 10-20 m. The third mass is in sandstone. It is an elongate oval in plan, 150 m long and 20 m wide, and is probably part of a flat-lying vein.

The formation of fractures was brought about by crustal movements resulting from tectonism and the intrusion of magma. The fault mentioned above was formed during the final stage of the tectonic movements, apparently after igneous activity had ended, or during its final stages. The formation of numerous fractures of varying attitude indicates that the faulting had been preceded by a relatively long interval during which smaller movements resulted in a belt of fractures along the course of the later faulting.

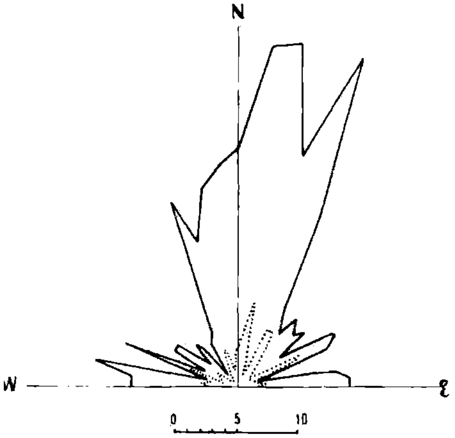

FIG. 1 - Rose diagram of the strike of dikes and veins on the Turja Peninsula.

The forms of the fissures later filled by the dikes and veins vary greatly. Some are rectilinear, with straight walls, and sometimes there are groups of parallel rectilinear fractures. However, most of the bodies are irregular — curving, braching, sometimes pinching and swelling, petering out and reappearing, with changing strike and dip. Their thickness ranges from 6 m to less than 1 cm, and their length of exposure varies from several meters to 300 meters.

The orientation of the 354 dikes and veins that have been recorded varies greatly, but 56 percent of them have strikes that lie within a sector of 45°, between azimuths of 340° and 25°, and 29 percent have strikes between 5° and 20°. Most of them dip eastward.

Most of the dikes and veins are in sandstone. Only 68 of them are in granite. In the rose diagram (Fig. 1) solid lines indicate the strikes of bodies that cut both granite and sandstone, and dotted lines indicate strikes of those that are exposed only in granite.

The compositions of the alkaline, subalkaline, calcite-silicate, and carbonate rocks of the Turja Peninsula have already been described

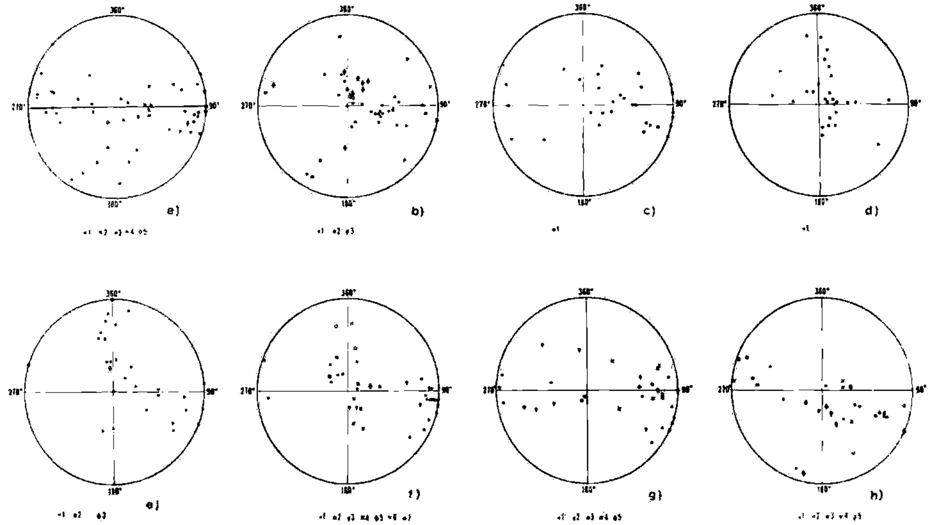

FIG. 2 - Projections showing the orientation of the poles of the planes of dikes and veins.
a): 1 - alkaline basalts, 2 - nepheline basalts, 3 - nephelinites, 4 - analcimites, 5 - basaltoïds.
b): 1 - ijolites, 2 - biotitic ijolites, 3 - malignites.
c): 1 - Turjaites.
d): 1 - Turjites.
e): 1 - melanocratic syenites, 2 - calcitic and quartz-calcitic alkaline syenites, 3 - alkaline « granite ».
f): 1 - carbonatites and calcitites, 2 - quartz-calcitic rocks, 3 - biotite-albite-calcite bearing rocks, 4 - fluorite-calcite bearing rocks, 5 - fluorite-quartz bearing rocks, 6 - fluorite amphibole bearing rocks, 7 - apatite-calcite bearing rocks.
g): 1 - melilite bearing basalt, 2 - melilite bearing porphyrite, 3 - melilite bearing nephelinite, 4 - melilitic rock, 5 - melilitic augitite.
h): 1 - augitite, 2 - alkaline augitite, 3 - nepheline bearing augitite, 4 - analcime bearing augitite, 5 - monchiquite.

by BELIANKIN and his pupils (1924*a*, 1924*b*, 1932), and by KRANK (1928). The spacial relationships of the most widely developed varieties establish certain regularities in their sequence of formation.

The poles, or normals, to the planes of the different types of dikes and veins are plotted in Fig. 2, *a* to *h*. Those for the dikes of ijolite (Fig. 2*b*), turjaiate (Fig. 2*c*) and melilitic rocks (Fig. 2*g*) fall close to those for dikes of the alkaline basalt group (Fig. 2*a*), those for the turjaites and melilitic rocks forming a more distinct zone with an east-west orientation. Most of the poles for the ijolite dikes and those for dikes of the alkaline basalt group also fall in east-west zones. The poles for the turjite dikes (Fig. 2*d*) fall in two relatively short zones, respectively E-W and N-S, and the dips characteristically are low. The poles for the syenitic dikes (Fig. 2*e*) lie in two zones, one of which strikes WNW and dips NNE, and the other strikes N-S and dips eastward. Steeply dipping calcite veins (Fig. 2*f*) strike NNE and dip ESE, while more gently dipping ones strike NW. Fluorite veins (containing calcite, quartz, or amphibole) dip E and SSE, quartz-calcite veins dip N, and biotite-albite-calcite veins dip E. The poles for augitite dikes (Fig. 2*h*) mostly lie in a zone trending WNW-ESE.

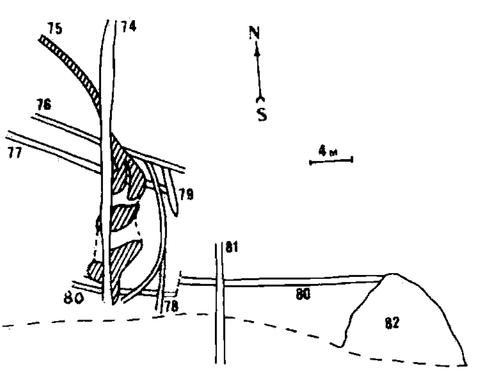

FIG. 3 - Network of veins 74 to 82. 74, 75, 76 and 77 = cancrinitized biotite ijolite; 78 and 79 = turjite; 80 = metamorphosed nepheline basalt; 81 = analcimized nephelinite; 82 = turjite and ijolite.

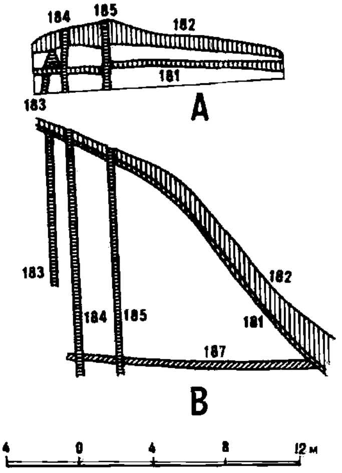

FIG. 4 - Cross section and plan of the dikes 181-187. 181-182 = turjite; 183, 187 = alkaline basalt; 184-185 = melilite porphyrite; 186 = carbonatite.

About 160 intersections of dikes and veins have been recorded. In many places the bodies form rather dense networks. Drawings of some of them (Figs. 3-9) and orientation diagrams (Fig. 10*a*-*g*) illustrate the complexity of the fracture systems within small areas. In the majority of cases the intersecting bodies are of different age and composition. Study of the patterns reveals the types of movement that caused the fractures, the order of different rock types that filled them, the sequence of types of rock alteration, and the change in character of the magmatic activity.

On the basis of the sequence of introduction of the different compositions of dikes and veins, three separate periods of igneous activity are recognizable (BELIANKIN and VLODAVETZ, 1932) (Fig. 11).

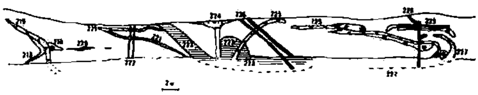

FIG. 5 - Network of veins 218-228.
218 = calcite fluorite bearing rock; 219 = metamorphosed nepheline augitite; 220 = metamorphic biotite ijolite; 221 = microturjite; 222, 223 = alkaline basalt; 224 = fluorite calcite bearing feldspatholite; 225, 226, 228 = augitite; 227 = micaceous porphyite.

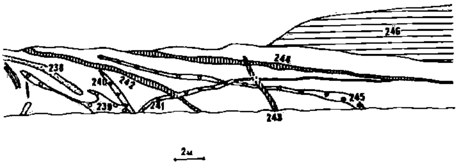

FIG. 6 - Network of veins 238-246.
238 = melilite porphyrite; 239, 245 = fluorite calcite bearing rock; 240-241 = nepheline augitite; 242 = biotite calcite bearing rock; 243, 244 = biotite ijolite; 246 = melanocratic syenite.

First, the sandstone was brecciated, then the fractures were filled with rocks of typically effusive texture — alkaline basalts followed by nepheline basalts and porphyrites, which later were metasomatically altered to albite-biotite-calcite rocks. This first period ended with the formation of a primary calcitic rock, probably a carbonatite. The rocks of the first period filled fractures that strike predominantly NNE and dip steeply eastward, but some veins strike WNW and dip southward. Only one dips northward.

Magmatic activity was most intense during the second period. Most of the rocks are panallotriomorphic granular intrusive types, in the following order: ijolite, turjite, turjaite, melanocratic syenite, and alkaline augitite. Locally, however, the sequence of intrusion began with turjite, followed by ijolite and other rocks. The period ended with the formation of fluorite-calcite and other carbonate rocks.

The second period was characterized by the abundance and activity of volatiles — water, fluorine, and especially carbon dioxide. The introduction of these substances and their combination with elements already present resulted in a change in the mineral composition of many of the rocks, not only the dike and vein rocks but the enclosing rocks as well. Sandstone was altered to a syenite-like rock, granite to fenite, and the minerals of dike rocks were replaced by analcite, cancrinite, and calcite. The syenitization of the sandstone was a regional metasomatism resulting from the introduction of alkalies. In deeper horizons this process reached the stage of anatexis, with the formation of a secondary magma which was then injected along fractures into overlying rocks, forming dikes of melanocratic aegirine syenite.

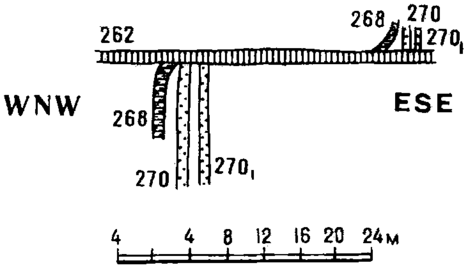

FIG. 7 - Intersecting veins 262, 268 and 270. 262 = metamorphic microijolite; 268 = alkaline basalt; 270 = fluorite calcite bearing rock.

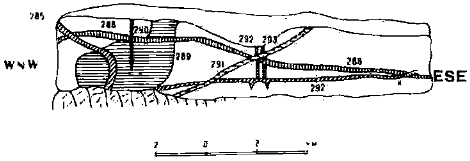

FIG. 8 - Network of veins 285-293. 285, 290 = melanocratic syenite; 288 = feldspathized biotite ijolite; 289 = calcitized volcanic breccia; 291 = alkaline basalt; 292 = calcite bearing syenite; 293 = eruptive breccia.

Most of the rocks of the second period were injected along wide east-west-trending fractures that dipped northward at angles ranging from gentle to steep. However, some of the veins strike NNE and dip gently to steeply eastward.

During the third period various rocks with textures typical of effusives were intruded approximately in the following sequence: monchiquite, alkaline basalt, alkaline augitite, augitite, nephelinite, nepheline basalt, melilitic rocks (alnoite, and others), alkaline augitite again, micaceous porphyrite, amygdaloid, and carbonatite. Rocks of the third period filled fractures striking northward, or nearly so, and mostly dipping eastward at angles varying from gentle to steep. A few of them dip westward.

Thus, three periods of igneous activity have been established in the Turja Peninsula and some degree of regularity (though admittedly not very great) has been determined in the orientation of dikes and veins formed during the different periods: those of the first period strike NNE and dip ESE, those of the second period strike east-west and dip north, and also strike NNE and dip ESE, and those of the third period strike north-south and dip eastward.

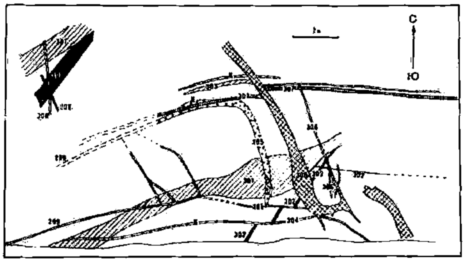

FIG. 9 - Network of veins 298-308.
298, 299, 304 = carbonatite; 301, 302, 303 = ijolite-turjites; 305, 306 = quartz and calcite bearing alkaline syenite; 307 = alkaline basalt; 308 = alkaline basalt (without olivine).

All of the alkaline and subalkaline rocks of the Turja Peninsula were derived from a magma that probably approximated ijolite in composition. The formation of certain other rock types resulted from

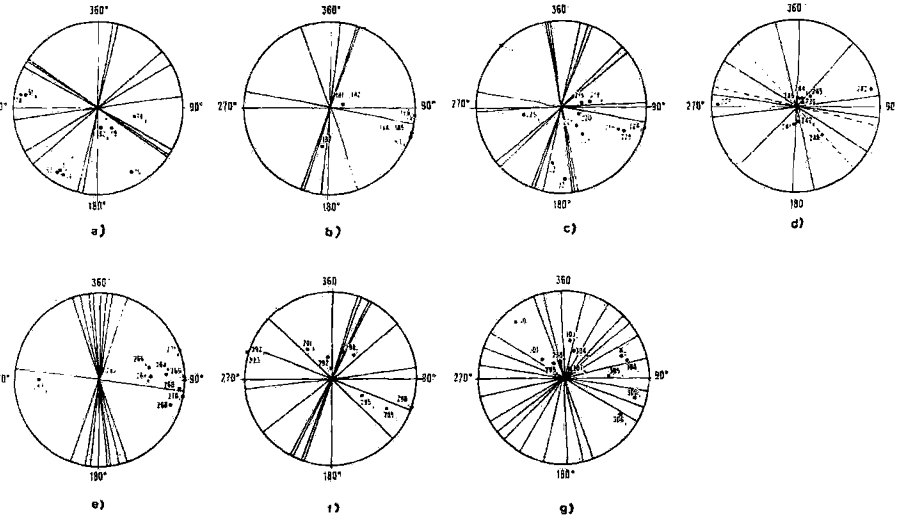

FIG. 10 - Orientation diagrams. *a*): Veins 74-82. Rock types as in Fig. 3; *b*): Dikes 181-182. Rock types as in Fig. 4; *c*): Veins 218-228. Rock types as in Fig. 5; *d*): Veins 238-246. Rock types as in Fig. 6; *e*): Veins 262-271. Rock types as in Fig. 7; *f*): Veins 282-293. Rock types as in Fig. 8; *g*): Veins 298-308. Rock types as in Fig. 9.

crystallization differentiation at different temperatures. Subsequent autometasomatic, metasomatic, and hydrothermal processes resulted in the formation of various carbonate-silicate rocks. A concluding stage in each period was the filling of fractures by carbonatites. It should be emphasized that there were repeated introductions, not only of carbonatites, but also of other rock types. Thus, alkaline basalts, nepheline basalts, nephelinites, and augitites were intruded during the first and third periods, and alkaline augitites were injected also during the second period.

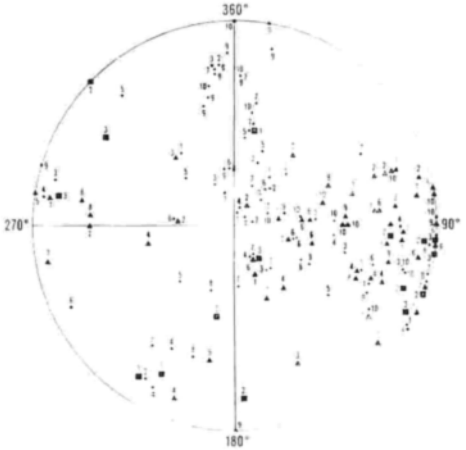

FIG. 11 - Projection showing the poles of the dikes and veins of the first (squares), second (dots) and third periods (triangles) of volcanic activity. Figures near the symbols indicate the sequence of dike or vein formation for each individual period.

It should be noted that fine grained rocks typical of surficial or shallow intrusive environments were formed during the first and third periods in the same horizon in which coarse grained rocks were formed during the second period. This apparently can be explained by a rapid rise of the magmatic material through cold enclosing rocks during the first and third periods, and a slower introduction of magma into intensely heated wall rocks during the second period. It is assumed that during the first period the enclosing rocks were still cold. During the second period the enclosing rocks were heated to high temperature at the time of the regional metasomatism of the sandstone to syenite-sandstone. Apparently the third period was preceded by a considerable interval of quiet, during which the enclosing rocks became cold again; and as in the first period, the movement of magma through them must have been rather fast.

Thus a quick ascent of magma through cold wall rocks during the first and third periods resulted in the formation of fine grained rocks with textures resembling those of typical effusives and extrusives, whereas the introduction of magma into hot wall rocks and its resultant slow cooling during the second period produced coarse grained rocks of typically intrusive textures.

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