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# CONTINENTAL RIFTING--A NEW TECTONIC MODEL FOR GEOTHERMAL EXPLORATION OF THE CENTRAL SEWARD PENINSULA, ALASKA

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## ABSTRACT

We propose that an interconnected system of late Tertiary to Quaternary rifts and transform faults may extend 250 km across the central Seward Peninsula. This concept may provide a useful model for future geothermal exploration of the area.

## INTRODUCTION

During our 1979 geothermal energy resource investigations at Pilgrim Springs, Alaska, (Figure 1) we developed the hypothesis that these hot springs were associated with tensional tectonics and active rifting. We also proposed that the low-lying region extending from the Imuruk Basin through the Kuzitrin valley to the Imuruk lava field represents an incipient rift through the Seward Peninsula (Turner and Forbes, 1980). In July 1980, we conducted a geological and geophysical reconnaissance of the central Seward Peninsula, designed to test the rift hypothesis and to provide information on the regional geothermal energy potential of the area.

## REGIONAL GEOLOGY AND GEOPHYSICS

Figure 1 shows the generalized geology of the Seward Peninsula as modified from Hudson (1977). The figure is designed to emphasize the distribution of basaltic lava fields and vents, Quaternary basins, and selected faults believed to be related to the proposed rift model.

A considerable body of geologic and geophysical evidence indicates that the Imuruk Basin-Pilgrim River valley (Figure 1) represents a graben or half graben structure. The Kigluaik Fault (Figure 1) is a major normal fault with displacement consistently down to the north. The fault marks the northern boundary of the Kigluaik Mountains and separates these mountains from the lowlands of the Imuruk Basin and Pilgrim River valley. Surficial mapping by Kline et al. (1980) suggests that relatively rapid subsidence has been occurring in the Pilgrim River valley.

Seismic studies in the Pilgrim River valley have shown that crystalline basement of the valley floor is about 400 m beneath Pilgrim Springs (Turner and Forbes, 1980). The total throw of the Kigluaik Fault is therefore at least 400 m. A gravity survey and a deep resistivity survey (Turner and Forbes, 1980) are consistent with the results of the seismic refraction study, although they cannot in themselves provide precise depths to basement.

Although there is no evidence of volcanic activity in the Imuruk Basin-Pilgrim River Valley region (Figure 1), the 1.5 $km^2$ geothermal anomaly at Pilgrim Springs and a second area of thawed ground about 3 km northeast are indicative of high heat flow in at least part of this region (Turner and Forbes, 1980).

The Imuruk Lake-Kuzitrin River lowland is a 30 km-wide, valley extending 100 km northeast from the Precambrian basement high cut by the Kuzitrin river to about 25 km northeast of Imuruk Lake (Figure 1). We have mapped a fault extending northeast about 60 km near the southern border of the lowland and named this fault the Kuzitrin Fault (Figure 1). The fault cuts Precambrian basement rocks along the northern front of the Bendeleben Mountains. Displacement is consistently down to the north. Glacial moraines are not present along the fault trace, but the fault has produced a scarp in colluvium north of Mt. Bendeleben, indicating Quaternary activity.

To the north of the Kuzitrin River lowland, a series of strikingly linear, northeast-trending parallel stream valleys are evident on landsat imagery and on the topographic maps of the area. Five of these lineaments are shown in Figure 1. Although they have not previously been mapped as faults (Sainsbury, 1974), their strong alignment, their parallelism to the Kigluaik fault and the fact that they border the Quaternary structural basin of the Imuruk Lake-Kuzitrin River lowland (Hopkins, 1963), suggest that these lineaments may represent en-echelon normal faults bordering a major graben.

The central and eastern parts of the Imuruk Lake-Kuzitrin River lowland are covered by the extensive alkali and tholeiitic basalt flows of the Imuruk Lake lava plateau (Figure 1). Hopkins (1963) mapped these volcanics and distinguished five volcanic units.

Alkali olivine basalt is the most common bulk composition in the Imuruk lava field, but some tholeiitic basalt is also present. The lava flows are relatively thin (3-20 m) compared to their large lateral extent (up to 35 km in length). Figure 1 shows the distribution of volcanic vents on the Seward Peninsula from Hopkins (1963) work. Near Imuruk Lake the vents form northwest-trending swarms parallel to observed surface faults. A series of vents and extensive flows also extend east and southeast along the Koyuk River valley. The abrupt offset of this valley to the south (Figure 1) suggests the presence of a major fault.

Hopkins (1963) has shown that faults in the northwest-trending system shown in Figure 1 delineate a broad graben occupied by Imuruk Lake. The faults cut the Imuruk and Gosling flows, but do not cut the Camille or Lost Jim flows, suggesting that the faults were active until late Wisconsin time but may not have been active during the last 10-15,000 years. Hopkins (1963) also postulated a structural trench in the Koyuk River Valley and on the site of the Kuzitrin flats (Figure 1).

## RIFT MODEL

We propose that a complex continental rift system, shown in Figure 2 may be responsible for the following late-Tertiary-to-Quaternary structural, tectonic, and volcanic features of the central Seward Peninsula:

(1) North-south extension and graben structures in the Imuruk Basin-Pilgrim River valley and Imuruk Lake-Kuzitrin River Lowland basins and in the Koyuk trench.
(2) Extensive outpourings of basalt lavas of the Imuruk Lake lava plateau and Koyuk River valley.
(3) Northwest alignment of volcanic vents and normal faults in the Imuruk Lava plateau and Koyuk River valley.
(4) The high level of seismicity in the central Seward Peninsula (Biswas et al., 1980).
(5) The presence of the Pilgrim Springs geothermal area and other evidence of anomalously high heat flow in the Pilgrim River valley.

The above evidence is consistent with the existence of rift segments B, C, D and E shown in Figure 3. We propose that these rift segments are offset by transform faults (Figure 2). Results of small scale (1:63,000) geologic mapping along the proposed offset between segments B and C show a lack of lithologic and structural continuity across the proposed transform boundary and an apparent offset of about 1 km.

Marine seismic reflection work (Grim and McManus, 1970; Hopkins et al., 1974; Johnson and Holmes, 1977) shows a major rift structure trending westward from Port Clarence under the Bering Sea. The 60 km-long valley located about 15 km north of Teller (Figures 1 and 2) may be the onshore continuation of this rift system, named the Port Clarence Rift by Hopkins et al. (1974). The valley is filled with Quaternary sediments and contains extensive basalt flows of Quaternary to late Tertiary age (Sainsbury, 1972; Hopkins et al., 1974). Basalt samples from this area are alkalic and show features, including ultramafic inclusions, similar to the Imuruk Lake basalts. K-Ar ages of these basalts are 2.5-2.9 m.y., similar to the ages obtained from the basalts of the Imuruk formation.

Having proposed the existence of rift segment A in Figure 2, we make two additional speculations:

1. the eastern end of segment A is connected to the western end of rift segment B by means of a north-south-trending transform fault, as shown in Figure 2.
2. The western end of segment A is connected to the Port Clarence Rift by means of a north-south-trending transform fault extending from the western edge of the basalt field southward to the Port Clarence Rift (Figure 2).

## HELIUM SOIL GAS SURVEY

Helium concentrations in soil gas were measured along five traverses across proposed rift segments A, B, C and D (Figure 2) and at various locations in the Pilgrim Valley. Helium, which is produced by the radioactive decay of the uranium and thorium series, has been shown to be a useful indicator of geothermal resources (Bergquist, 1979). The normal atmospheric He content is 5.24 ppm, and our commercial analysis has a precision of ± 0.01 ppm.

Figure 3 is a map of the Seward Peninsula showing the locations of sampling sites and helium anomalies greater than 5.4 ppm. Significant helium anomalies on all traverses which occur only within 10 km of the center of the proposed rift segments with the exception of two small anomalies at the north end of the Imuruk traverse. The largest anomalies were in the Pilgrim Valley near the Pilgrim Springs KGRA, but large anomalies were also found on the Imuruk and Agiapuk traverses. These warrant more detailed exploration for geothermal resources.

## SUMMARY AND CONCLUSIONS

We propose the complex continental rift model shown in Figure 2 as an explanation for many of the late Tertiary-to-Quaternary topographic, structural, tectonic and volcanic features of the central Seward Peninsula, and for the rift structure offshore in the Bering Sea. Although some features of the model are highly speculative, we believe that the body of geological and geophysical evidence consistent with the model is sufficient to support the model as a working hypothesis to be tested by future field work. He anomalies are localized at or near segments of the proposed rift, suggesting the presence of abnormally high heat flow.

The model implies that the central Seward Peninsula is spreading apart in a north-south direction. We have not yet been able to do geologic mapping at the eastern end of the proposed rift system and the eastern termination of the rift system is purely speculative, based on the limited geologic data base for the area.

We have not discussed the extensive basalt fields in two northsouth-trending valleys in the northeast corner of the peninsula or the large basaltic field west of Cape Espenberg (Figure 2). Following the rift model, it is perhaps possible that the basalts in the two north-south-trending valleys could represent flows from leaky transform faults parallel to the proposed transforms of the model.

The possible existence of a major rift system extending 250 km across the Seward Peninsula is of major significance for regional geothermal energy resource assessment. The proposed rift segments should, in general, be areas of higher heat flow than their surrounding regions. The proposed rift system should be considered as an exploration model for future geothermal studies on the Seward Peninsula.

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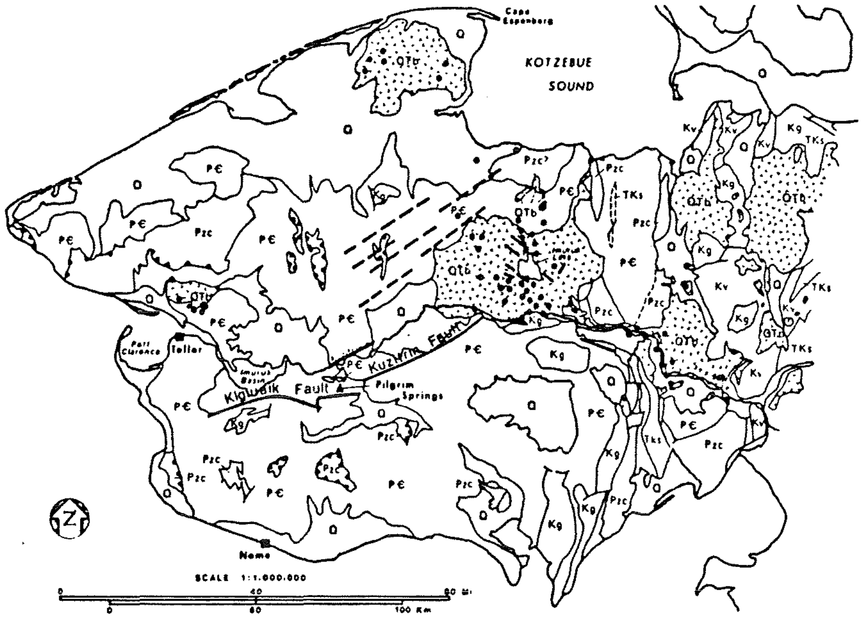

Figure 1. Generalized geology of the Seward Peninsula showing distribution of basaltic lava fields (QTb), vents (dots), Quaternary basins (Q) and selected faults.

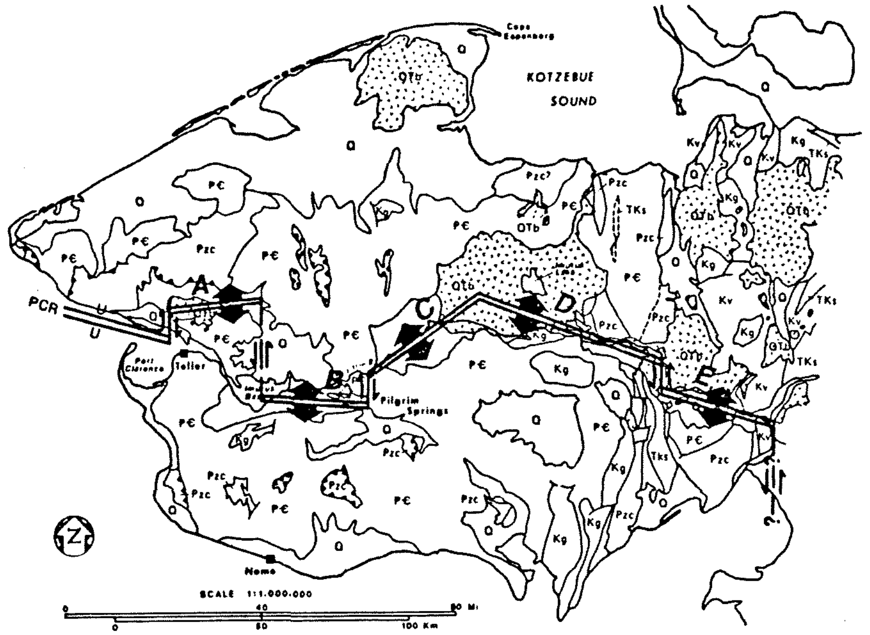

Figure 2. Diagram of proposed rift model for the central Seward Peninsula. The graben structure offshore (PCR) is the Port Clarence Rift (Hopkins et al., 1974) Geology generalized from Hudson (1977). See text for discussion.

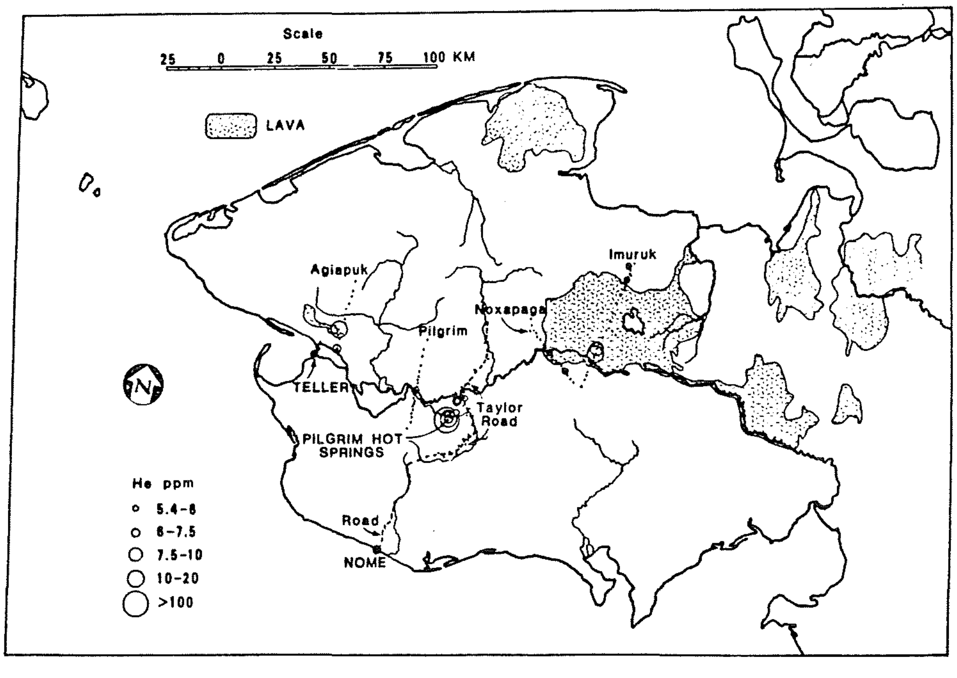

Figure 3. Station locations of helium soil samples on five traverses across proposed rift sections A-D, and significant anomalies.