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HELIUM AND MERCURY IN THE CENTRAL SEWARD PENINSULA

RIFT SYSTEM, ALASKA

by

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Abstract

The central Seward Peninsula, Alaska, has one Known Geothermal Resource Area (KGRA) at Pilgrim Springs, and has recent volcanic flows, fault systems, topographic and tectonic features which can be explained by a rift model. As part of a geothermal reconnaissance of the area we used helium and mercury concentrations in soil as indicators of geothermal resources. The largest helium concentrations were found in the vicinity of the Pilgrims Springs KGRA, and indicate prime drilling sites. Five profile lines were run across the suspected rift system. Significant helium anomalies were found on several of the traverses, where future exploration might be concentrated. Mercury values showed a great range of variability on the traverses, and seem unreliable as geothermal indicators except in the vicinity of the Pilgrim Springs. Permafrost at the surface resulting in variations in sampling depth may contribute to the mercury variations.

Introduction

Turner et al., 1981, have proposed "that an interconnected system of late Tertiary to Quaternary rifts and transform faults extends 250 km across the central Seward Peninsula from Port Clarence to the eastern Koyuk River Valley". The rift model appears to explain many late Tertiary to Quaternary topographic, structural, tectonic and volcanic features, and should be useful as an exploration model for geothermal energy resources. Figure 1 shows a diagram of the proposed rift system on a generalized geological map.

As part of a study of the Seward Peninsula geothermal energy potential during summer 1980, geological mapping, remote sensing, geophysical exploration and geochemical sampling methods were used to develop the rift model and search for geothermal resources. Previous work in 1979 at the Pilgrim Springs KGRA had delineated the near surface reservoir, which shallow drilling confirmed.

The Seward Peninsula covers approximately the same area as the state of West Virginia, but with very few roads. In order to search for evidence of other hidden geothermal resources in this large area we tried using helium and mercury in soil samples as indicators. Both have been reported as useful in exploration for geothermal areas and they can be sampled fairly rapidly and are inexpensive to analyse.

Helium anomalies near geothermal sites have been detected near geothermal sites throughout the world (Bergquist, 1979). Two factors may contribute to helium anomalies in conjunction with geothermal areas: The deep, nonatmospheric mixing source of most geothermal waters, and the radioactive decay of uranium and thorium in the vicinity of the source waters. Helium is unusual in that its solubility in water increases with temperature above 30°C [Figure 2 after Mazor (1972)]. Pressurized hot water will be a very efficient scavenger of helium produced by radioactive decay of uranium and thorium contained in the rocks at depth, and will release it as it rises towards the surface, cools and de-pressurizes. Since helium is highly mobile it will find faults, minute fractures and paths to rise to the surface. Some helium will be trapped in the rocks and sediments, but because its atomic structure is nearly spherical the entrapment is difficult (Bergquist, 1979).

We sampled the soil for helium in two ways: The first was to drive a probe 30 in. into the ground and draw off a ground gas sample which was then inserted into a small evacuated steel ampule and sealed for later analysis. This method does not work well in wet soil or where the soil is rocky or frozen. In such conditions we used a soil sampling auger to drill a hole 30 in deep. The soil core at the bottom was then quickly placed in a tin can and sealed. Western Systems, Inc., performed the helium analysis to a precision of 10 parts per billion. Normal atmospheric He concentration is 5.24 ppm, and any significant soil concentration above this is an anomaly.

Mercury content in soils has also been reported as a possible indicator of geothermal resources (Matlick and Buseck, 1975). They confirmed a strong association of Hg with geothermal activity in three of four areas tested (Long Valley, California; Summer Lake and Klamath Falls, Oregon). Mercury deposits typically occur in regions containing evidence of geothermal activity, such as hot springs (White, 1967).

Mercury is very volatile. The high vapor pressure makes it extremely mobile, and the elevated temperatures near a geothermal reservoir tend to increase this mobility. The Hg migrates upwards and outwards away from the geothermal reservoir, creating an aureole of enriched Hg in the soil above a geothermal reservoir larger in area than a corresponding helium anomaly.

We collected soil samples about 10 cm below the organic layer. The samples were air dried in the shade and sized to -80 fine using a stainless steel sieve. The -80 portions were stored in airtight glass vials for analysis. The Hg content of the sample was determined by use of a Jerome Instrument Corp., model 301 Gold Film Mercury detector with sensitivity to better than 0.1 ng of Hg. A standard volume of -80 mesh soil (0.25 cc) is placed in a quartz bulb and heated red hot for one minute to volatize all of the Hg, which is collected on a gold foil. Heating of the gold foil in the analysis procedure releases the Hg for analyses as a gas in the standard manner. Calibration is accomplished by inserting a known concentration of Hg vapor with a hypodermic syringe.

The background concentration of Hg in soils varies widely from area to area, and must be determined from a large number of samples. It is generally the order of 10 parts per billion.

A question remained as to the application of helium and mercury sampling to Alaska geothermal exploration: How does the presence of permafrost affect the diffusion of He and Hg from source to the soil surface? Further basic resarch on this problem is needed, but we do know that we found both He and Hg anomalies in both thawed and in thick permafrost areas.

Prior to the work on the Seward Peninsula rift system we tried both He and Hg sampling in the vicinity of Chena Hot Springs, Alaska. Figure 3 shows a map of Chena Hot Springs with isothermal contours at a depth of 0.5 m, and the soil concentrations of He and Hg in the area. A high value of 795 ppm He was found near the center of the 40°C isotherm at the west end of the area. In general the mercury values tended to outline the same linear anomaly presumed to be a fault in the underlying quartz monzonite crystaline rocks.

He and Hg Results in Central Seward Peninsula

In order to further assess the usefulness of He and Hg surveys some limited profiles were made in the approximately 1 km^2 thaw ellipse at Pilgrim Hot Springs. Figure 4 shows a map of Pilgrim Springs and the location of anomalous He samples. The highest soil concentrations of about 100 ppm He were found near, but not at the highest temperatures at 4.5 m depth (80°C). Figure 5 shows the T, He and Hg values along a profile west to east across the hottest temperature anomaly. In general the helium and mercury values are in agreement. Both are anomalously high at station 20°W which is suggested as a prime drilling site. Along a north-south profile on the 0.0 line the helium values were all close to atmospheric levels, yet a mercury anomaly of 55 ppb was found at a location where the ground temperature was only 20°C. Curiously samples next to the main hot springs pool were low in both He and Hg. The cause of this is likely due to the soil which is a porous sand, and the elevated temperature. The porosity of the soil could allow helium to readily pass through to the atmosphere. Mercury would be easily vaporized by the high temperature and also escape through the porous soil.

Some anomalous helium values were found outside the thaw ellipse across the Pilgrim river as shown in Figure 4. Galvanic and EM-16R resistivity measurements show low resistivity layers beneath the surface and suggest the presence of geothermal water in a band along the river.

There is a second smaller thaw window in the Pilgrim river valley 4 km ENE of Pilgrim Springs. The temperature at 4.5 m was 20°C. The He concentration in the soil was anomalous, 5.52 ppm, and Hg samples were indeterminate, some low some higher than normal. No drilling or deeper temperature measurements have been made, but resistivity measurements indicate a low resistivity layer of 2.5 Ω-m at depth.

As geological mapping progressed in 1980 the general outlines of a proposed rift system emerged. Except for the Nome Taylor Road, all access to the area was by helicopter or boat. Five traverse lines were planned to cross the elements of the rift system to measure gravity, geology, VLF, mercury and helium wherever possible. The limited helicopter and field time did not permit stations as closely spaced as might be desirable.

Figure 6 shows a map of the Seward Peninsula with the location of stations on the five traverse lines. Also shown are the locations of anomalous He soil concentrations found. With the exception of two small anomalies at the north end of the Imuruk Traverse, all the helium anomalies lie within the proposed rift sections A, B, C, or D (Figure 1). Helicopter flying range did not allow us to work farther to the east in segment E.

Figure 7 shows a geologic cross section, and the He and Hg concentrations along the Imuruk Traverse. There are two significant helium anomalies two km apart in the lava fields not far from the recent Lost Jim Flow. The Hg values are also high at these two stations.

Figure 8 shows a geologic cross section at the western end of the rift system where the highest helium anomaly on the traverses was located. The corresponding Hg soil concentration is about normal. On the traverse several large Hg anomalies were found, particularly in a small stream valley at station 128. The cause of this anomaly is not evident. At one time during the gold rush mercury was used to amalgamate the fine placer gold in streams. We tested a soil sample in Quartz Creek which was heavily mined and found the Hg content about average. There was no evidence of mining actively in the valley of station 128, or at 131 which was also anomalous. The Hg aureole is expected to be much larger than that around an He source, so the fact that no He anomaly was found at either station does not rule out a geothermal source of the Hg.

Space does not permit the inclusion of other traverses. In general however the Hg values showed great variability from one station to another, while the He values were almost all near background except for a few anomalies shown on Figure 6.

Conclusions

Our use of He and Hg in the study of the Central Seward peninsula was in part research into the usefulness of these geothermal associated elements. We found that both are probably useful in a hot springs or known thermal anomaly. However as reconnaissance tools we found that the Hg soil concentrations showed great variability. If we had made closer spaced measurements we might be able to explain the variability, but as it is we can only speculate. Perhaps the presence of permafrost affected the ability to collect samples at a uniform soil horizon. There are probably more varied sources of Hg in the rocks than it is the case for He. We found the He sampling produced anomalies in the rift zones, and several significant concentrations which indicate areas of interest for future geothermal exploration.

APPENDIX A

Geological Map Units

Q QTu	Tertiary to Quaternary alluvium, valley fill, includes Kougarok gravels and equivalents, till and alluvium.
QTb Qb	Tertiary to Quaternary basalts of the Kuzitrin Flats and Eva Mtn. Alkalic to Tholeiitic in composition with ultramafic inclusions in the alkali basalts.
Ki	Cretaceous intrusives, mostly quartz monzonite.
Pz Pzc	Thrust sheets of Paleozoic carbonates and meta-carbonates.
PG PGms	Precambrian to lower paleozoic metasediments. Schists and gneisses of the Nome Group and York Slate. Locally migmatized in the Northern Bendeleben Mts.

Geologic units generalized from Hudson (1977) and Sainsbury (1972, 1974) with faults on the Imuruk Traverse by Hopkins (1963).

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FIGURE CAPTIONS

Figure 1. Diagram of proposed rift model for the central Seward Peninsula. The graben structure offshore (PCR) is the Port Clarence Rift (Hopkins et al., 1974). The geology is generalized from Hudson (1977). QTb unit are late Tertiary to Quaternary basaltic lava flows. See Appendix A for geologic units.

Figure 2. Solubility of noble gases in fresh water (after Mazor, 1972).

Figure 3. Map of Chena Hot Springs, Alaska with 0.5 m depth isothermal contours, helium and mercury soil concentrations.

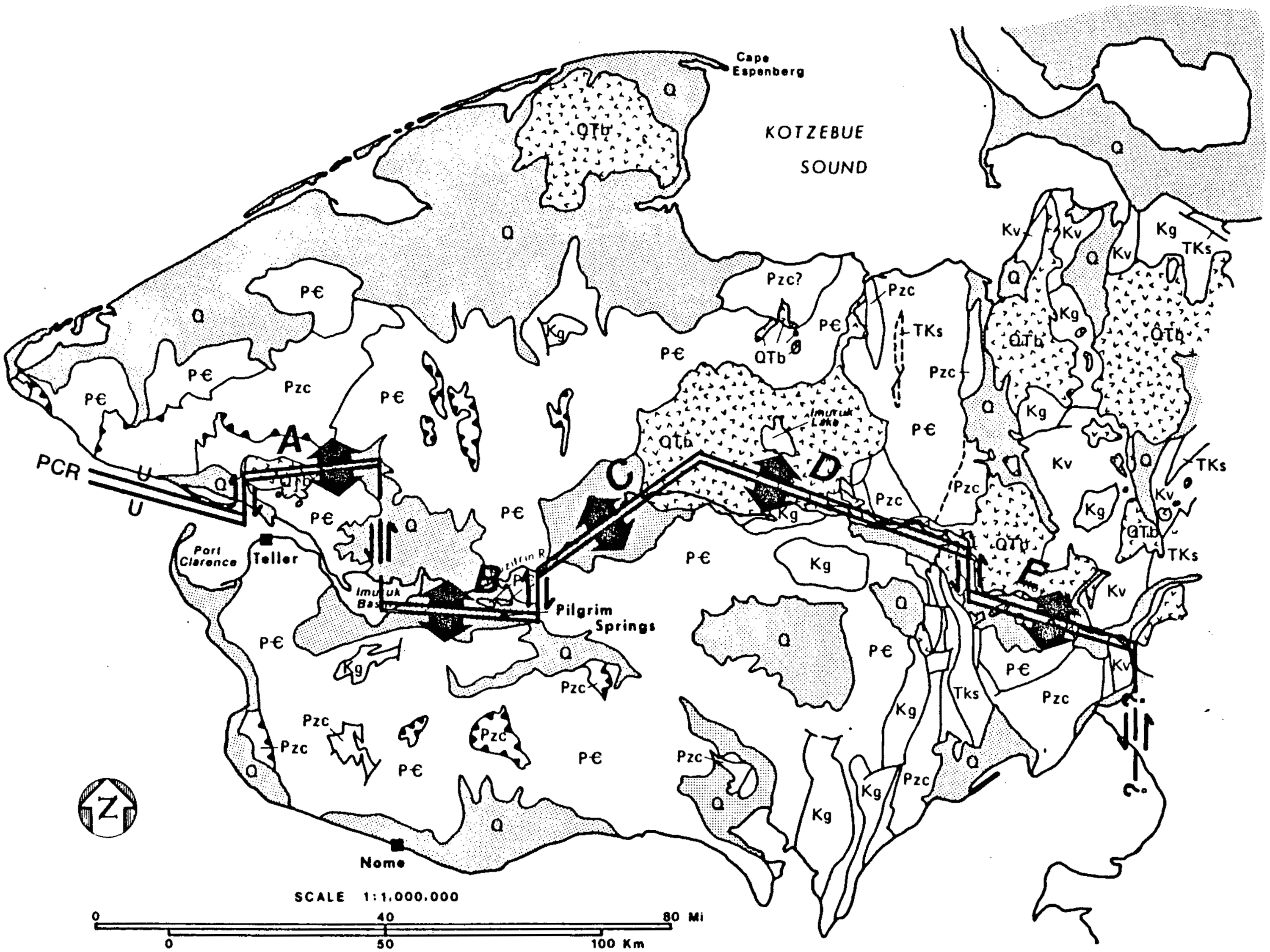
Figure 4. Map of Pilgrim Hot Springs, Alaska showing the elliptical area of thermally disturbed ground and anomalous He values found.

Figure 5. Temperature at 4.5 m depth, He and Hg soil concentrations in a west to east profile across the Pilgrim Hot Springs thaw ellipse.

Figure 6. Map of Seward Peninsula, Alaska showing 5 traverse lines across sections of the proposed rift system and locations of anomalous helium soil concentrations.

Figure 7. Imuruk traverse, helium and mercury soil concentrations. Two significant helium anomalies are found at stations 43 and 44. The mercury values are also higher than the mean at those sites. The nearby Lost Jim Flow is of very recent age. See Appendix A for geologic units.

Figure 8. Agiapuk traverse, helium and mercury soil concentrations. A significant helium anomaly was found at station 123 near lava flows of probable Tertiary age. Two large Hg anomalies were also found without He concentrations. See Appendix A for geologic map units.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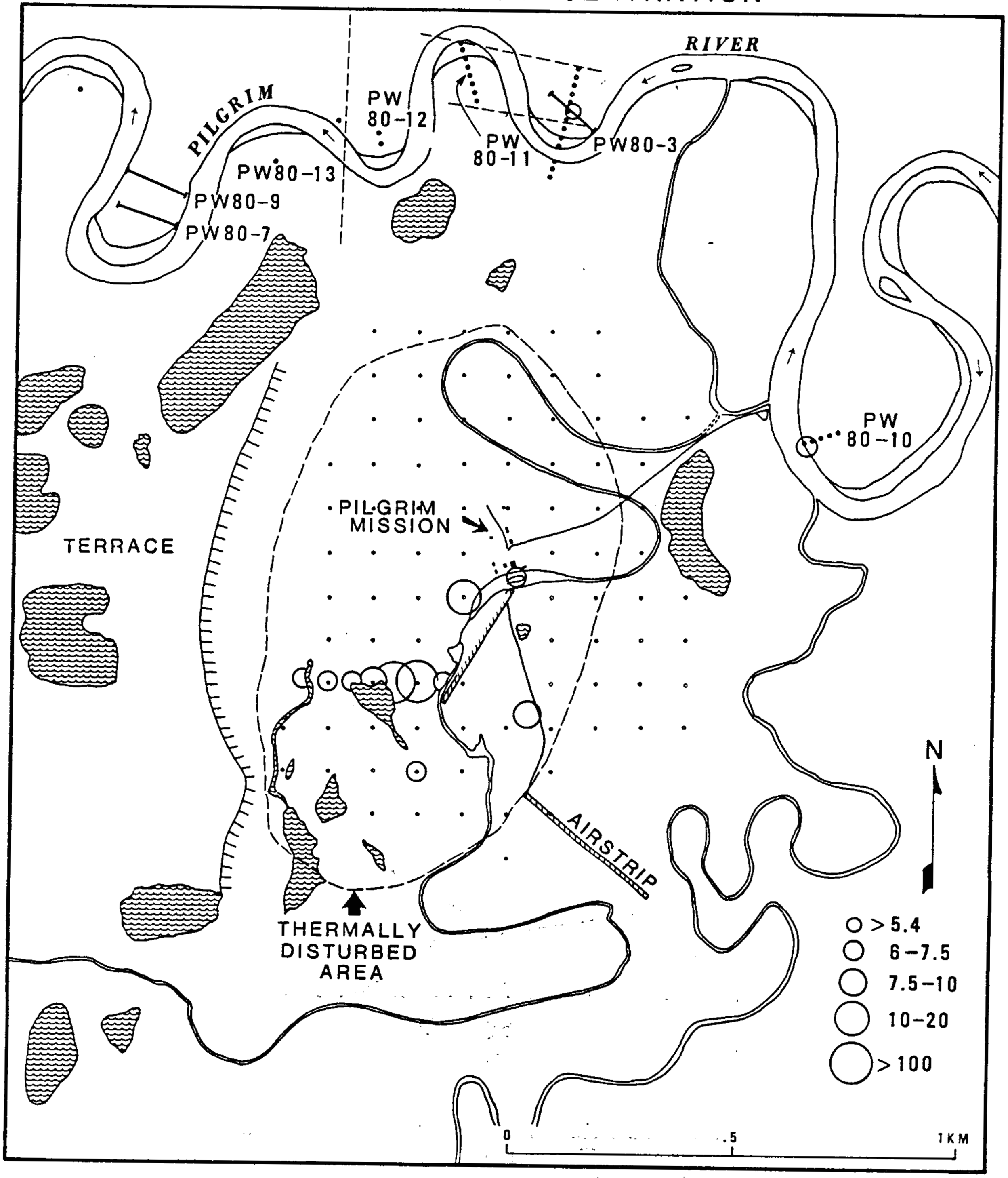
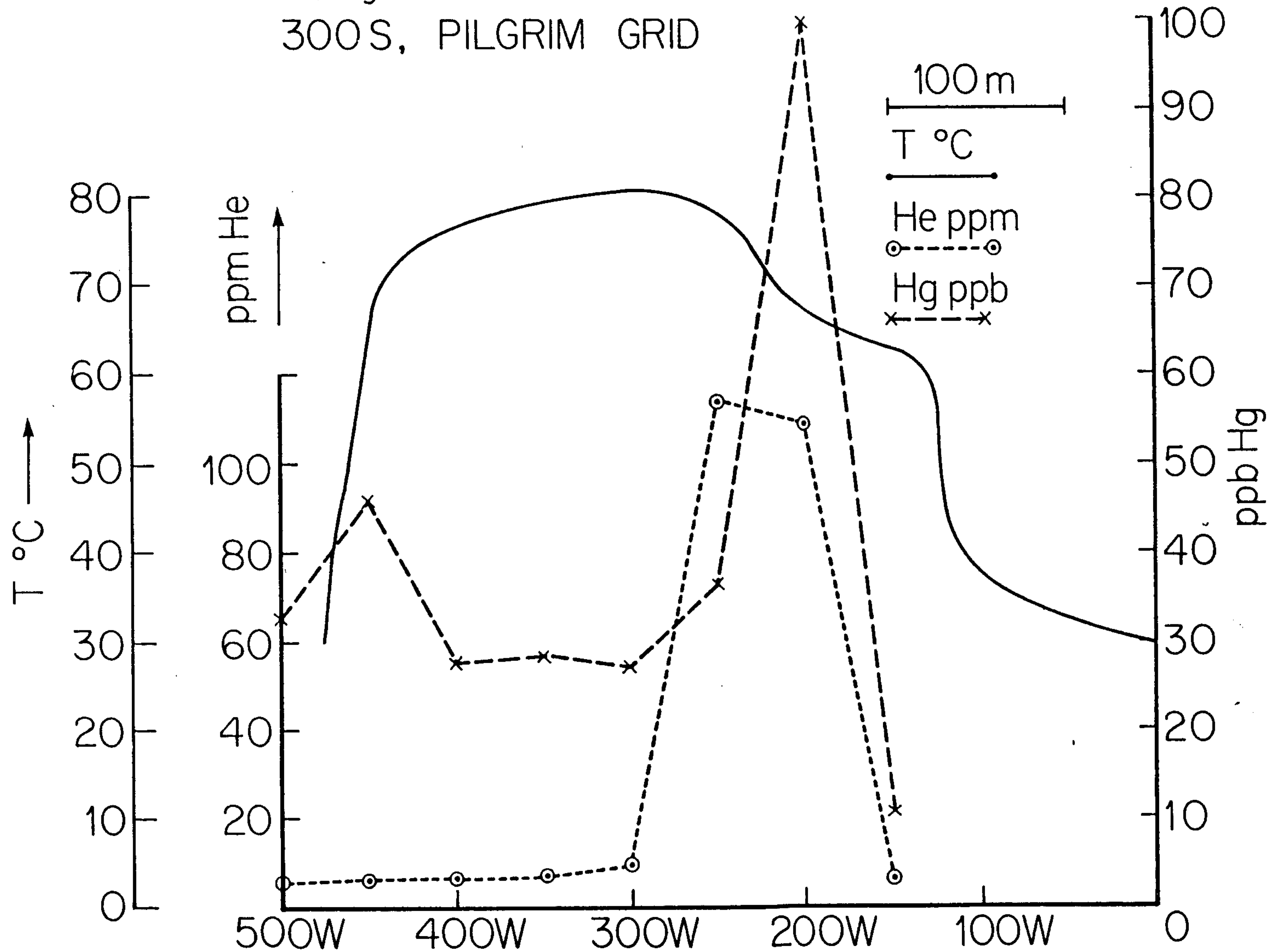
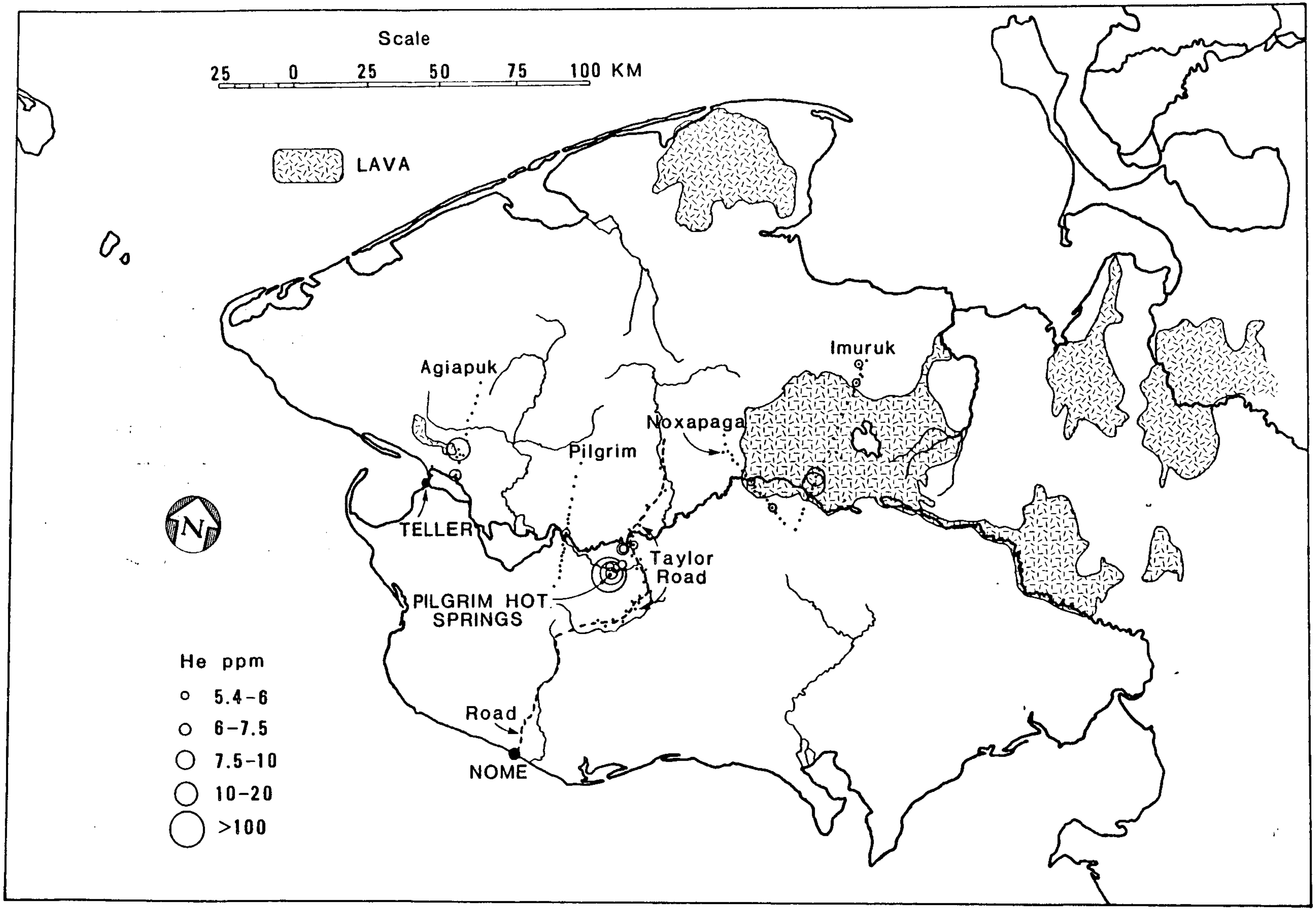
HELIUM SOIL CONCENTRATION



4.5mT, Hg & He PROFILE ALONG
300 S, PILGRIM GRID

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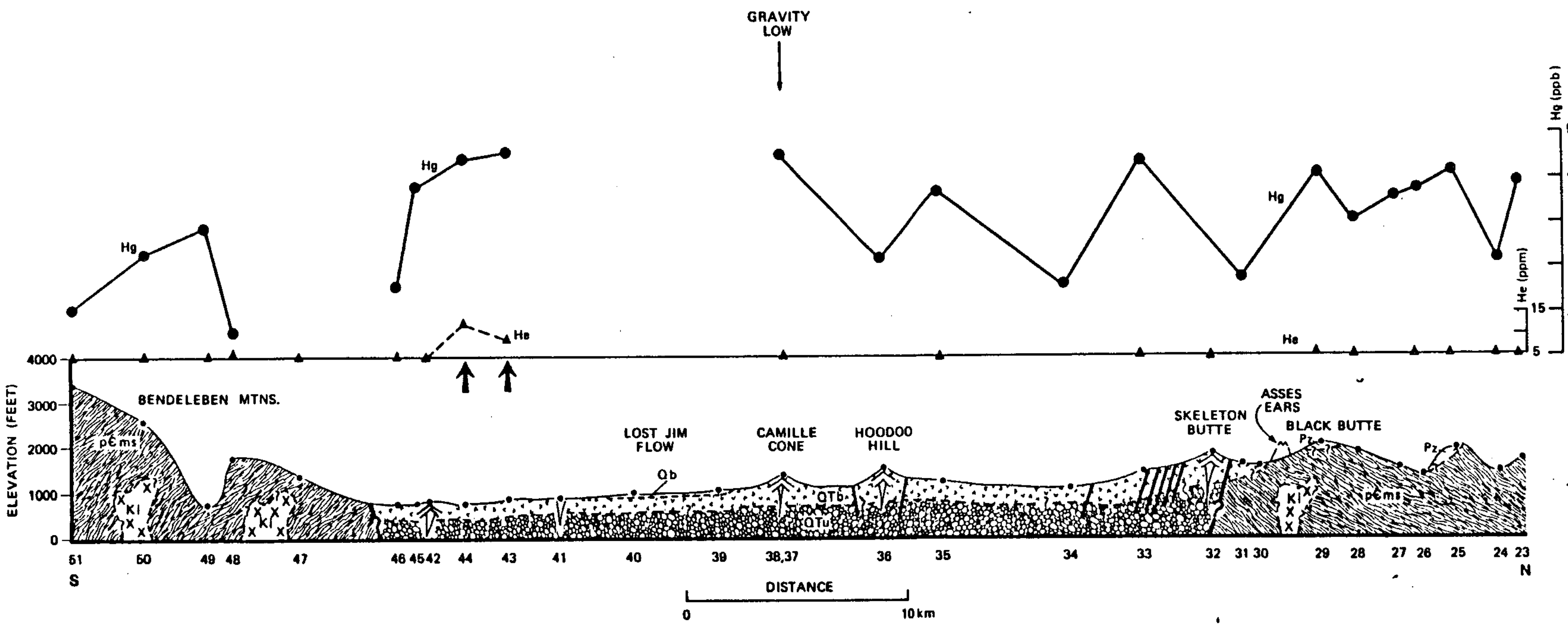
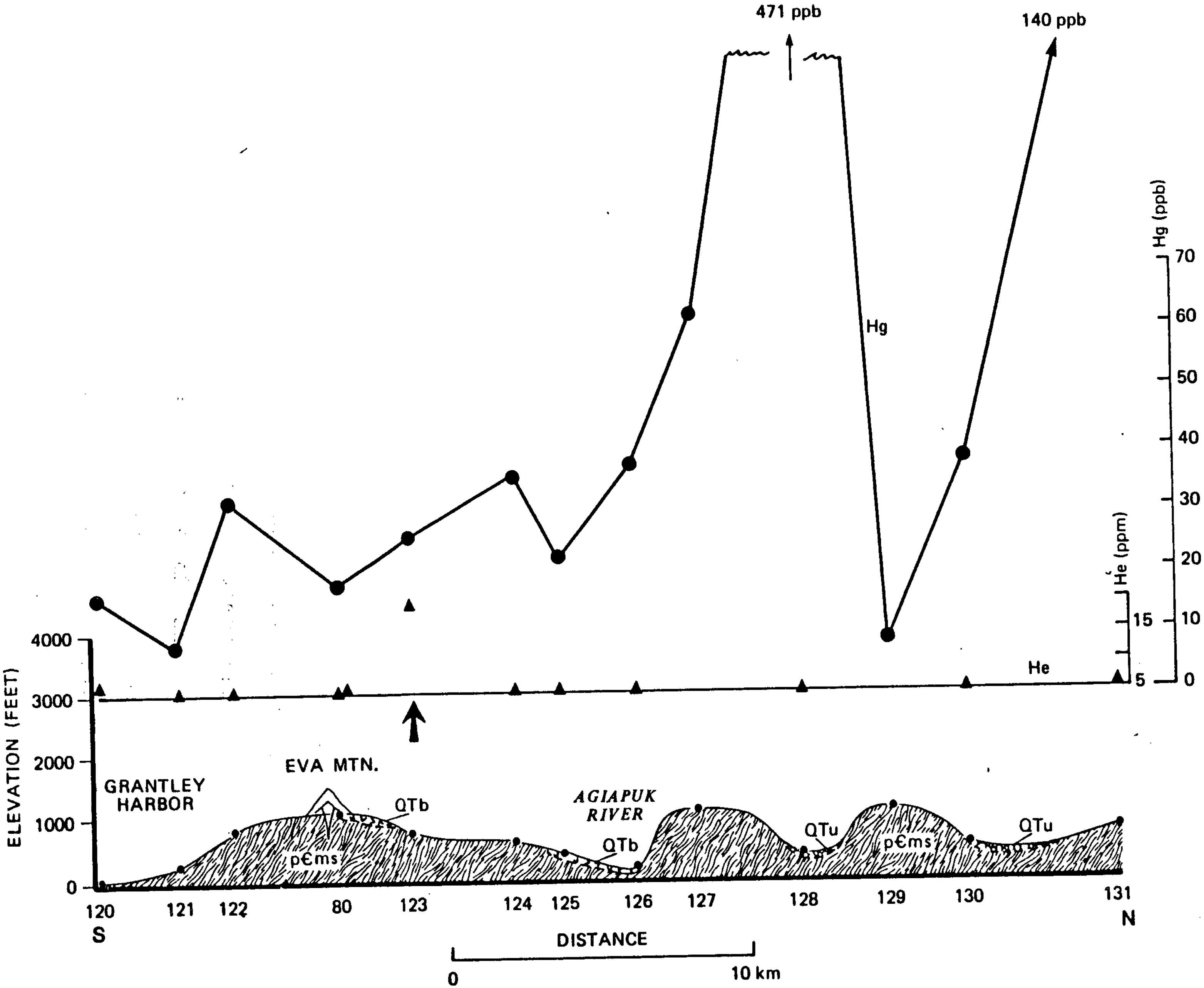


IMURUK TRAVERSE



AGIAPUK TRAVERSE