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Limitations on Genesis of Uranium Ores, Midnite Mine, Washington, Based on Lead-Uranium Ages

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LIMITATIONS ON GENESIS OF URANIUM ORES, MIDNITE MINE, WASHINGTON, BASED ON LEAD-URANIUM AGES

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Oxidized and reduced uranium minerals that make up the Midnite uranium deposits occur in metapelite and metacarbonate rocks of the Middle Proterozoic Togo Formation adjacent to a Cretaceous porphyritic quartz monzonite pluton (fig. 1). Numerous genetic hypotheses have been proposed, and all suffer from lack of definitive geologic and geochemical evidence. The present distribution of uranium minerals probably reflects destruction and redeposition of earlier formed minerals, and distribution of original uranium minerals is highly conjectural. Our new data do not answer many questions, but do place limits on viable genetic mechanisms and their times of operation. We offer the following new information, some of which constrains genesis.

Age of pluton.--U-Th-Pb ages from zircon in porphyritic quartz monzonite exposed in the Boyd 2 pit are 75 ± 2 m.y. Apatite from this locality yields a fission-track age of 69 ± 6 m.y. U-Th-Pb ages from zircon in porphyritic quartz monzonite collected at Turtle Lake are 90 ± 2 m.y. Fission-track ages on apatite and sphene from the Turtle Lake locality are 80 ± 8 m.y. and 82 ± 3 m.y. respectively.

Pb isotope systematics.--Isotopic analyses of many rock and ore samples indicate that common Pb is enriched (~645 ppm) in pitchblende and coffinite, and that Pb tends to follow the distribution of U. Analyses of barren pelites, pyrrhotite, and K-feldspar from the quartz monzonite show grossly similar Pb isotopic ratios, which are consistent with Pb evolution from a Cretaceous S-type granitic rock formed from crustal rocks. The amount of radiogenic Pb observed is much smaller than would be generated if there was Proterozoic uranium mineralization in the Togo.

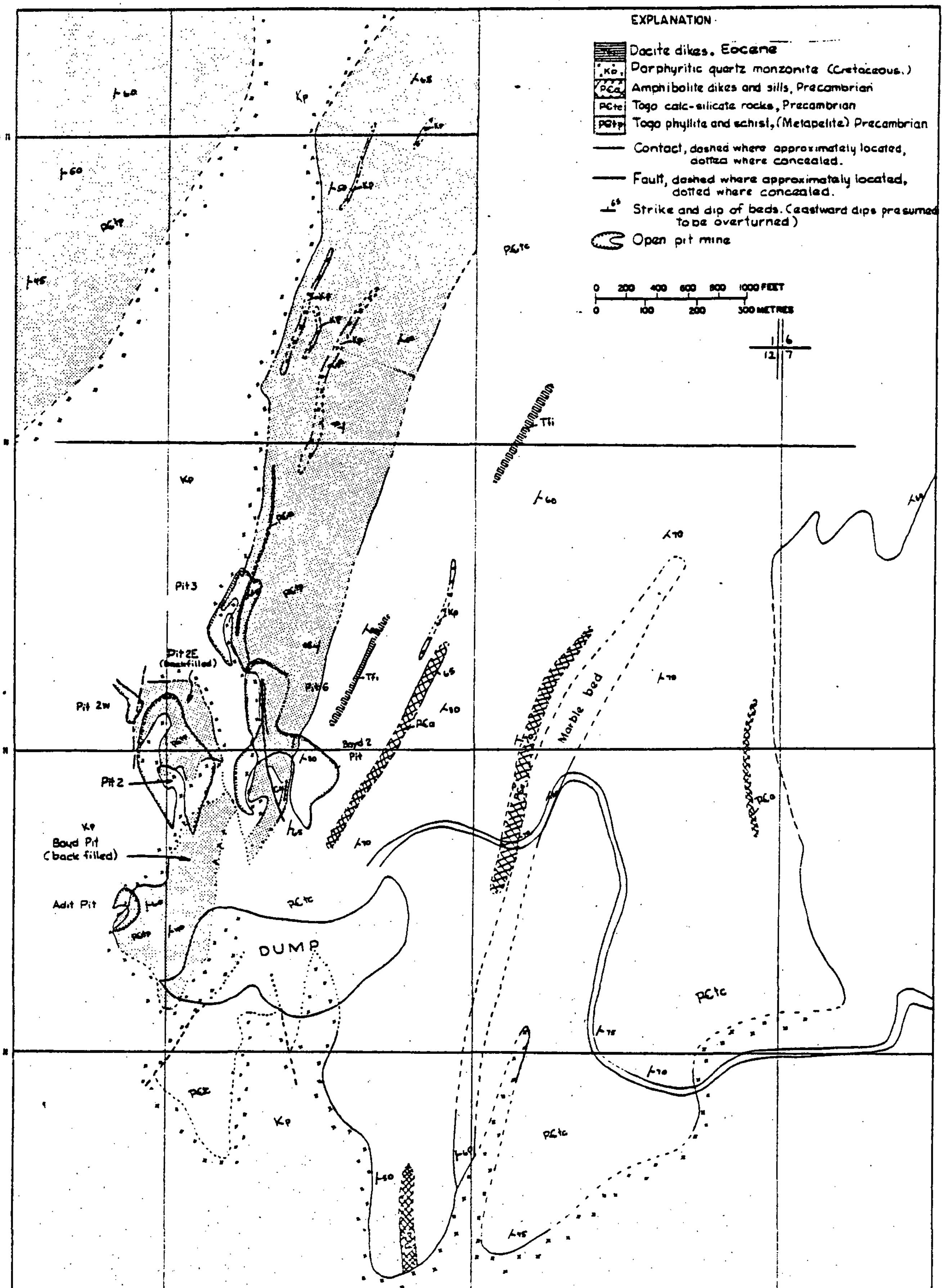

Figure 1.--Geology of the Midnite Mine.

Age of ores.--Eight high-grade, unoxidized ore samples from drill core and mine exposures yield $^{207}Pb/^{235}U$ ages in the narrow range from 50 to 52 m.y. (fig. 2). The fact that all ore samples examined yield essentially the same date, regardless of location, suggests that the Eocene event was widespread. Of course we cannot show this for all parts of all ore zones.

Age of Sanpoil Volcanics.--Extrusive rocks of the area, and associated feeder dikes, previously termed Gerome Andesite, have been renamed Sanpoil Volcanics, and dated by the potassium-argon method at 51 ± 2 m.y. (Pearson and Obradovich, 1977). A new K-Ar determination by R. F. Marvin, H. H. Mehnert, and V. Merritt of the USGS (written commun., 1979) on hornblende from a dacite dike in the Boyd 2 pit yielded an age of 51.8 ± 3.1 m.y. Fission-track ages from zircon and apatite in the same sample are 47.2 ± 1.9 and 47.5 ± 3.6 m.y. respectively, which we interpret to record the same intrusive event.

Post-intrusion alteration.--Alteration effects that followed contact metamorphism in metasediment include alteration of calc-silicates to clays (time unknown) and argillic alteration in and along dacite dikes. The observation that fission tracks in a sample of apatite from the quartz monzonite at the mine were not reset in the Eocene requires that the immediate area not have been heated to more than 100°C for long periods ($>\sim$ 1 m.y.).

Geology in the Eocene.--Sanpoil Volcanics rest unconformably on the quartz monzonite 800 m south of the mine, and dacite dikes are known in the orebodies and near the top of Spokane Mountain 2 km north of the mine. These observations suggest that the morphology of the area was approximately the same in the Eocene as it is today and that an unknown thickness of Sanpoil Volcanics covered the mine area. North-trending faults occupied by dikes were active in the Eocene and locally intense fracturing and shearing can be related to Eocene tectonism judging from deformation of dikes. Distribution of volcanic rocks indicates that drainage was to the south; hence the hydraulic gradient probably also was from north to south.

Paragenesis.--The sequence of mineral deposition in dated samples is pitchblende plus pyrite prior to and overlapping coffinite. Marcasite began crystallizing with coffinite. Hisingerite (hydrous iron silicate) seems to have formed contemporaneously with both pitchblende and coffinite. The age of coffinite is not measurably different from that of pitchblende. Beyond dated samples we have no absolute geologic or mineralogic criteria for establishing older or younger stages of reduced uranium minerals. Oxidized uranium

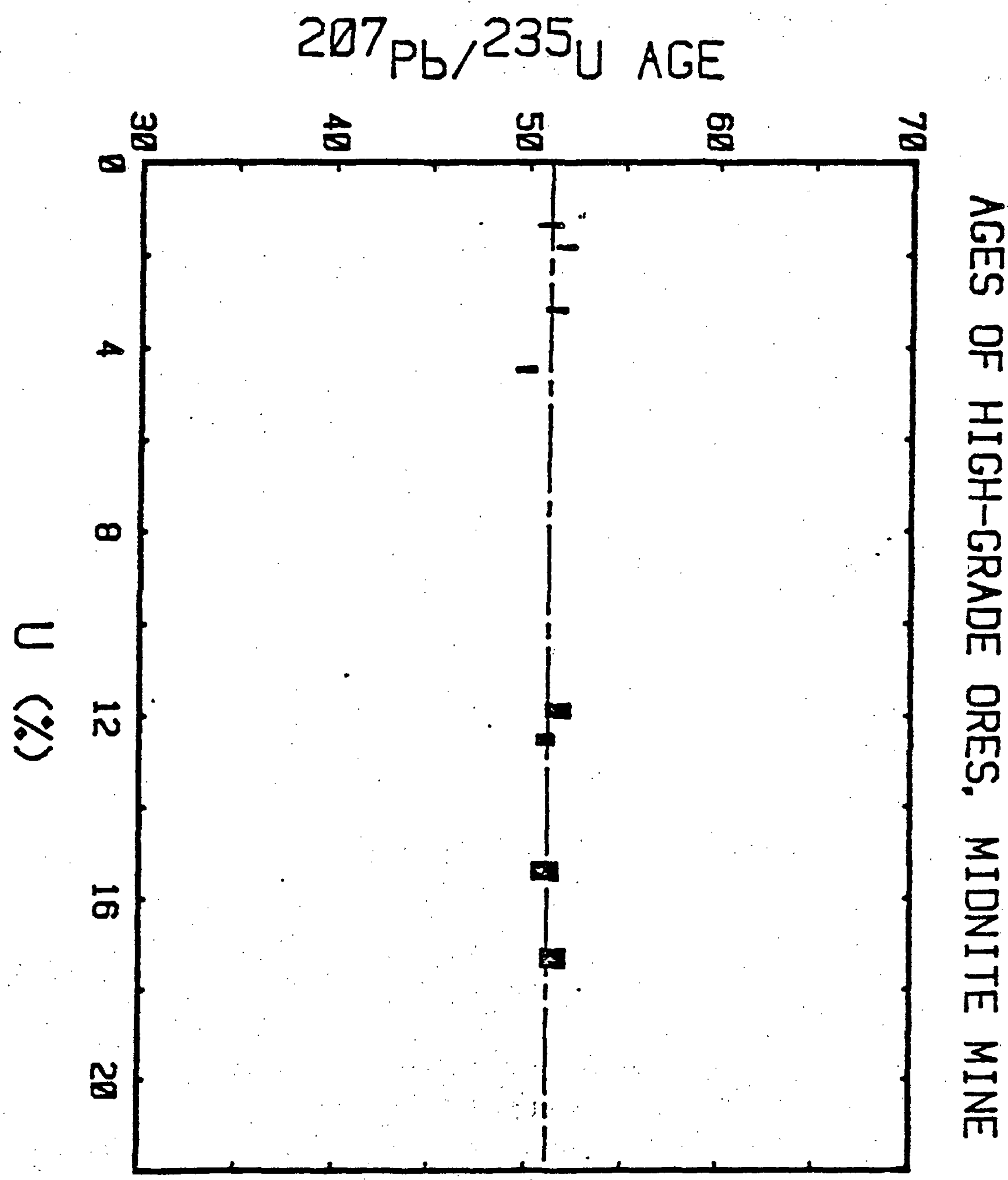

Figure 2.--Pb-U ages of high grade uranium ores, Midnite Mine.

minerals continue to form at and above the present water table.

Source of uranium.--Whole-rock analyses (19) of the porphyritic quartz monzonite of the Midnite Mine show an average of 14.7 ppm U and 32.1 ppm Th by neutron activation analysis (Nash, 1979). Selection of the 14 freshest samples raises the averages to 17.0 ppm U and 34.7 ppm Th. Sanpoil Volcanics are not notably radioactive and their plutonic equivalents contain about 5 ppm U. It appears that uranium content of zircon can be used to estimate probable rock content and that it is not subject to surface leaching (Silver, 1976). Uranium content of zircon samples from the porphyritic quartz monzonite averages 4,000 ppm and suggests about 20-50 ppm U originally in the rock.

INTERPRETATION

Three hypotheses of origin discussed previously (Nash, 1977) are limited by the new data reported here. The small amount of radiogenic lead found in analyzed samples of ore, wallrock, and sulfide minerals is additional evidence that the Togo Formation probably did not contain uranium deposits or high concentrations of uranium in the Proterozoic. Available data do not support the hypothesis that Sanpoil Volcanics was a source of uranium for the deposits. We continue to favor the porphyritic quartz monzonite of the Midnite Mine as the source of uranium. We speculate that uranium was derived from the pluton during its intrusion and crystallization about 75 m.y. ago, although no observational evidence exists for many parts of the hypothetical hydrothermal introduction. We propose that the 51-m.y.-old event recorded in U-Pb isotopes of ore samples was one of pervasive redistribution, not primary uranium emplacement and crystallization.

The magmatic-hydrothermal source (Nash, 1977) is preferred despite many unproven aspects. The porphyritic quartz monzonite is the most uraniferous and fertile source rock known in the area (Nash, 1979) and probably supplied most of the uranium. We hypothesize that uranium was introduced into he Togo at about 75 m.y., then remobilized into the present sites at 51 m.y. by near-surface fluids flowing below Sanpoil Volcanics. Insufficient volume of uraniferous pluton would have been available for leaching in quantity to explain all of the uranium known in the mine area, but a portion of the ores may have been derived by supergene leaching of the pluton. Additional uranium could have been leached from Togo phyllites, particularly if metamorphism liberated syngenetic uranium bound to carbon so that it could be easily leached.

The age equivalence of ores and Sanpoil Volcanics is not considered to be fortuitous. At this time the following features could have combined to enrich uranium:

(1) Intense fracturing and shearing that accompanied and followed intrusion of feeder dikes.

(2) Covering Sanpoil Volcanics would have changed ground-water hydrology and possibly was an additional factor in channeling ground water into structural traps.

(3) Sanpoil Volcanics and feeder dikes would have heated ground water and accelerated reactions that caused either leaching or deposition of uranium.

(4) The mild thermal event (hot springs system) probably drove wallrock reactions that produced hydrogen sulfide or metastable polysulfide ions. Hydrogen sulfide can be smelled today escaping from dikes and the dacite fault zone.

(5) The Sanpoil Volcanics would have provided good protection for uranium deposits.

A possible and highly speculative general hypothesis proposes subhorizontal flow of oxygenated (but not sulfate-rich) groundwater through sulfidic and uranium-rich (100 ppm?) Togo Formation, leaching of uranium and formation of metastable thiosulfate or sulfite ions, and flow into structural traps. Metsastable sulfur species could break down at those sites, or their breakdown would be accelerated if temperatures increased (C. G. Warren, oral commun., 1979). Sulfide ion produced from sulfide mineral reactions or decomposition of metastable sulfur species is proposed to be the reductant for uranium and also the sulfide ion for ore stage pyrite and marcasite. Formation of marcasite rather than pyrite appears to occur when thiosulfate or sulfite decomposes (Goldhaber and others, 1978). Partial oxidation is considered to be an important constraint because formation of the observed reduced sulfide and uranium minerals from sulfate-rich fluids would probably require biogenic processes and these are not likely in graphitic rocks.

The Eocene age of mineralization and the interpretation that it represents redistribution may have important implications for finding deposits similar to those of the Midnite mine. A characteristic of the magmatic-hydrothermal mechanism, if it indeed operated, may be a tendency to form lowgeneral sense, several different processes may be possible for upgrading. Structural traps and iron sulfide appear to be important ingredients, but it is not clear if a volcanic-mild hydrothermal environment is required.

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