Geologic controls of mineralization in the Tallahassee Creek uranium district, Fremont County, Colorado

by

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Geologic Controls of Uranium Mineralization

in the Tallahassee Creek Uranium District, Fremont County, Colorado

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Abstract

Two important orebodies have been defined by drilling in the Tallahassee Creek uranium district, Fremont County, Colorado. They are the Hansen orebody, which contains about 12 million kg of U_3O_8, and the Picnic Tree orebody, which contains about 1 million kg of U_3O_8. Host rock for the Hansen is the upper Eocene Echo Park Alluvium, and host rock for the Picnic Tree is the lower Oligocene Tallahassee Creek Conglomerate. Average ore grade for both deposits is about 0.08 percent U_3O_8.

The principal source rock for the uranium deposits is the lower Oligocene Wall Mountain Tuff, although a younger volcanic rock, the Oligocene Thirtynine Mile Andesite, and Precambrian granitic rocks probably also contributed some uranium. Leaching and transportation of the uranium occurred in alkaline oxidizing ground water that developed during alteration of the ash in a semi-arid environment.

The uranium was transported in the ground water to favorable sites where it was deposited in a reducing environment controlled by carbonaceous material and associated pyrite.

Localization of the ore was controlled by groundwater flow conditions and by the distribution of organic matter in the host rock. Ground-water flow, which was apparently to the southeast in Echo Park Alluvium that is confined in the Echo Park graben, was impeded by a fault that offsets the southern end of the graben. This offset prevented efficient discharge into the ancestral Arkansas River drainage, and protected chemically reducing areas from

destruction by the influx of large amounts of oxidizing ground water. The location of orebodies in the Echo Park Alluvium also may be related to areas where overlying rocks of low permeability were breached by erosion during deposition of the fluvial Tallahassee Creek Conglomerate allowing localized entry of uranium-bearing water. Paleohydrology in Tallahassee Creek Conglomerate may have additionally been controlled by the alteration of pervious ash beds to impervious clay beds.

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Introduction

Two important orebodies, the Hansen and the Picnic Tree, have been outlined by drilling in the Tallahassee Creek uranium district about 35 km northwest of Canon City in Fremont County, Colorado (figs. 1, 2). The Hansen orebody is in the upper Eocene Echo Park Alluvium and it contains about 12 million kg of U_3O_8. The Picnic Tree orebody is in the lower Oligocene Tallahassee Creek Conglomerate and contains about 1 million kg of U_3O_8. The average grade for both these deposits is about 0.08 percent U_3O_8 (Cyprus Mines Corporation, 1980). The above figures show that the reserves of U_3O_8 in the Tallahassee Creek district are greater than combined reserves and production at the important Schwartzwalder deposit in the Ralston Buttes district in Jefferson County, Colorado. The uranium operations in the Tallahassee Creek district are known as the Hansen Project, which is a joint venture of Cyprus Mines Corporation and Wyoming Minerals Corporation.

The purpose of this report is to present a preliminary discussion of the geologic controls of uranium mineralization in the Tallahassee Creek district. The controls believed important and considered in this report are as follows: (1) source of uranium, (2) geochemical conditions of leaching, (3) paleohydrology, (4) character of host rock, (5) concentrating mechanism, and (6) preservation.

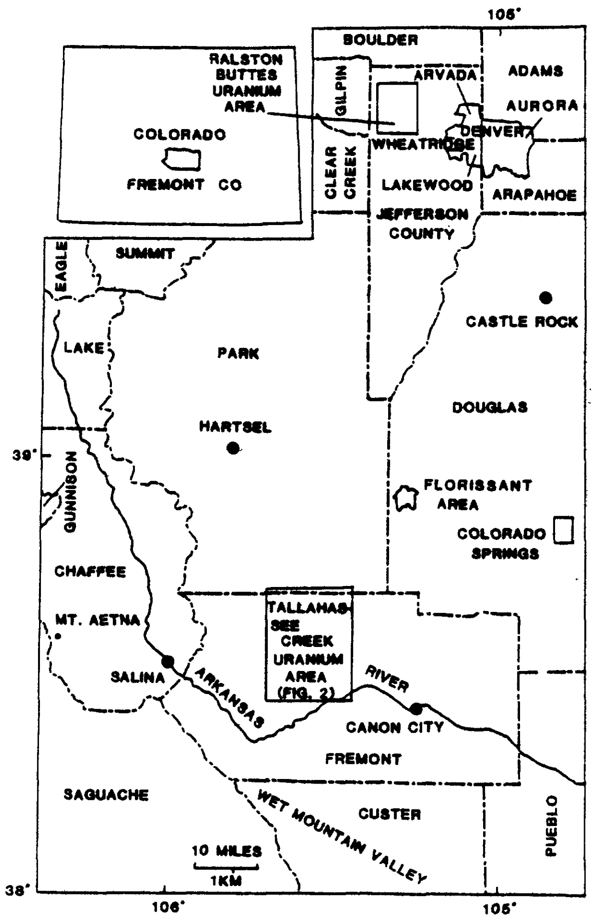

Figure 1.--Location map of the Tallahassee Creek Uranium Area, Fremont County, Colorado.

The report is based on published work and on data collected during 1979 for the Department of Energy National Uranium Resource Evaluation (NURE) of the Pueblo NTMS 1^{o} x 2^{o} Quadrangle (Dickinson and Hills, 1980). About 100 samples of potential source and host rocks were collected in the vicinity of the Tallahassee Creek uranium district. Uranium and thorium values for these samples were obtained by the neutron-activation technique, and chemical analyses were obtained by the six-step semiquantitative spectrographic method in the laboratories of the U. S. Geological Survey in Colorado. Mineralogical data were obtained from thin sections and by X-ray diffraction. Several small surficial orebodies in the area were examined.

No direct subsurface data on the orebodies were available, but some information was obtained from Cyprus Mines Corporation, (Cyprus Mines Corporation and Wyoming Minerals Corporation, 1979; Cyprus Mines Corporation, 1980). Volcanic geology in the area was largely worked out by Epis and Chapin (1968, 1974). Geologic history of the area was summarized by Epis and others (1976, 1980). Maps of the area were authored by Scott and others (1978), Taylor and others (1979), Wobus and others (1979) and Epis and others (1979).

Geology

During the late Eocene a widespread low-relief weathered surface was developed on Precambrian, Paleozoic and Mesozoic rocks in the vicinity of the present Colorado front range (Epis and others, 1976, 1980). The upper Eocene Echo Park Alluvium was deposited on this surface. As the Echo Park was deposited, grabens formed as renewed uplift and associated faulting began to take place. About 35 to 36 million years ago, in the early Oligocene, large areas of the low-relief surface were covered by the Wall Mountain Tuff, an andesitic to rhyolitic ash-flow tuff that originated somewhere to the west, perhaps near Mt. Aetna (Epis and others, 1976), and extended over the Tallahassee Creek area (fig. 2). The Wall Mountain tuff extended as far northeast as Castle Rock and as far southeast as the Wet Mountain Valley. This tuff tended to follow and to be thicker in the valleys. The Echo Park graben (fig. 2), was the site of one of these paleovalleys. The Oligocene Tallahassee Creek Conglomerate formed in channels on the Wall Mountain Tuff surface. The conglomerate contains many boulders of the tuff. Deposition of the Tallahassee Creek Conglomerate was brought to a close when volcanic materials from the lower member of the Thirtynine Mile Andesite became interbedded with and eventually covered the conglomerate. The upper member of the Thirtynine Mile Andesite was dated at about 34 million years (Epis and Chapin, 1974). Additional volcanic, fluvial, and lacustrine sediments were added to the geologic column during the remainder of the Oligocene and in the Miocene and Pliocene.

The Echo Park graben extends from Echo Park near the Arkansas River northwestward for about 70 km to the vicinity of Hartsel in Park County (Scott and others, 1978). The graben is about 8 km in width at its widest point. Much of the graben is covered by rock from the Thirtynine Mile volcanic field and the exact location of the bounding faults is not known in some areas (fig. 2). Precambrian granodiorite of Boulder Creek age (about 1700 m.y.) underlies the graben and protrudes through the younger rock at some locations in the graben floor. The southern end of the graben may be partly or completely detached and moved relatively westward along a strike-slip fault that may be related to the Texas Creek fault farther south. The Tallahassee Creek uranium district lies in the southern part of this graben. The Salida-Waugh Mountain paleovalley enters the graben in the vicinity of the uranium district (Epis and others, 1976).

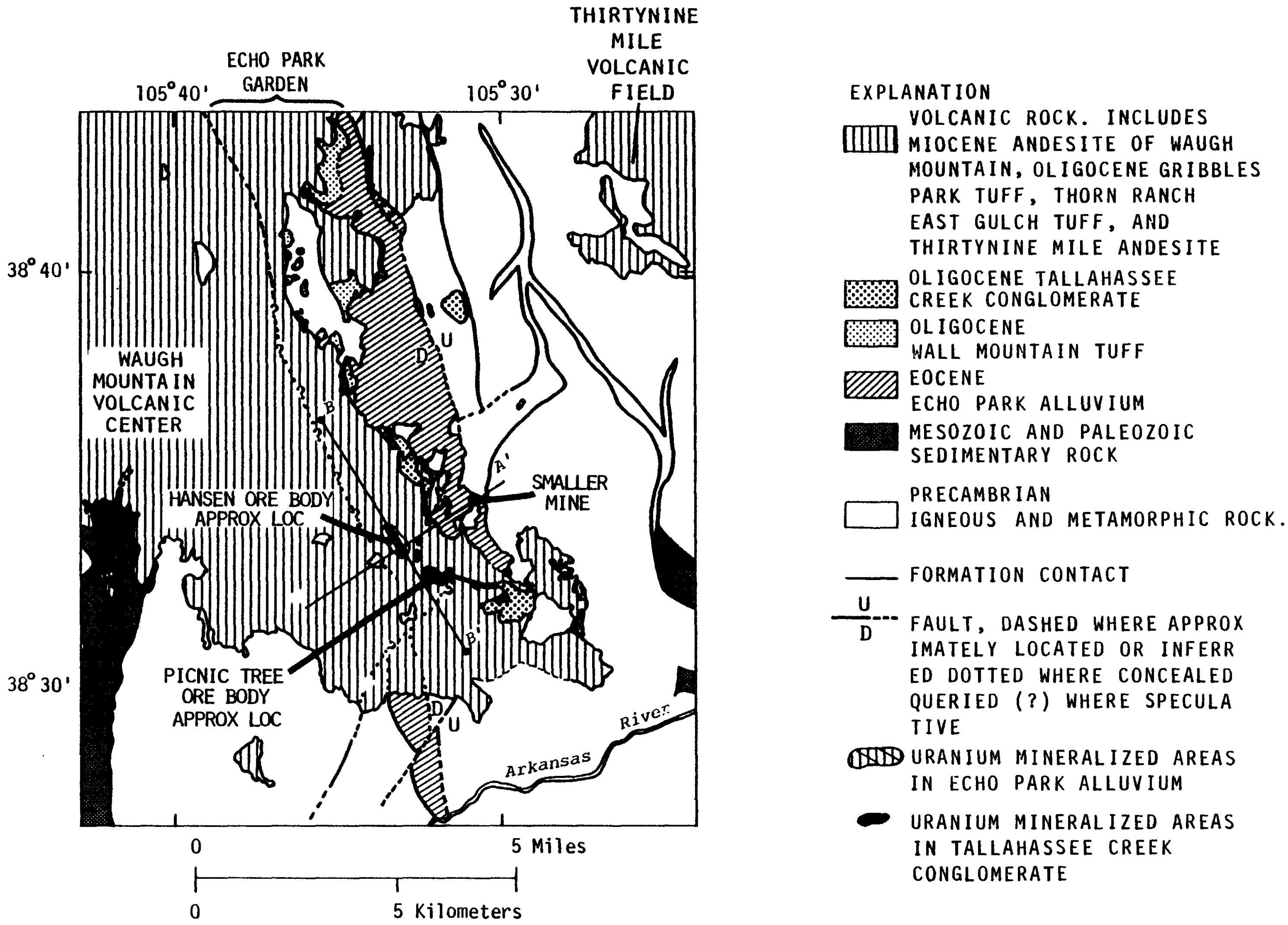

Figure 2.--Generalized geologic map of the Tallahassee Creek area showing uranium deposits and locations of cross sections (figure 4).

The Echo Park Alluvium generally consists of shale, quartzose to arkosic sandstone, and sandy conglomerate. It contains two prinicpal facies, a poorly sorted colluvial or sheetwash facies and a fluvial facies. The fluvial facies, which was deposited in channels composes 5 to 30 percent of the unit (Epis and Chapin, 1974). The colluvial facies has been divided into sheetwash and fanglomerate subfacies, and the fluvial facies has been divided into a lower conglomerate, a middle fairly well sorted pebbly sandstone, and an upper clayey sandstone and mudstone unit (Cyprus Mines Corporation, 1980). The fluvial facies contains carbonaceous material. The Echo Park Alluvium reaches 240 m in thickness in the graben.

The Wall Mountain Tuff consists of rhyolitic ash-flow tuff, up to 30 m thick in the Echo Park graben. The unit contains phenocrysts of sanidine and generally weathered andesite. The tuff is mostly devitrified but is partly black vitrophyre (Epis and Chapin, 1974).

The Tallahassee Creek Conglomerate contains a variety of cobbles and boulders chiefly derived from Precambrian crystalline rock and Tertiary volcanic rocks. The conglomerate was deposited in roughly meandering channel that crosses the Echo Park graben in a southeasterly direction (fig. 3). Boulders of Wall Mountain Tuff up to 5 m in diameter are common in the unit. The matrix is mainly arkosic sandstone. Nearly pure ash beds and tuffaceous beds containing subangular to angular boulders of andesite from early eruptions of the Thirtynine Mile volcanic center are interbedded in the upper part of the Tallahassee Creek Conglomerate. One prominent ash bed at the top of the conglomerate that has been partly altered to montmorillonite and kaolinite is informally called the "bentonite bed." This same unit, which generally ranges from 1 to 3 m in thickness, is termed the ash fall member of the Tallahassee Creek by Cyprus Mines Corporation (1980). The ash fall member

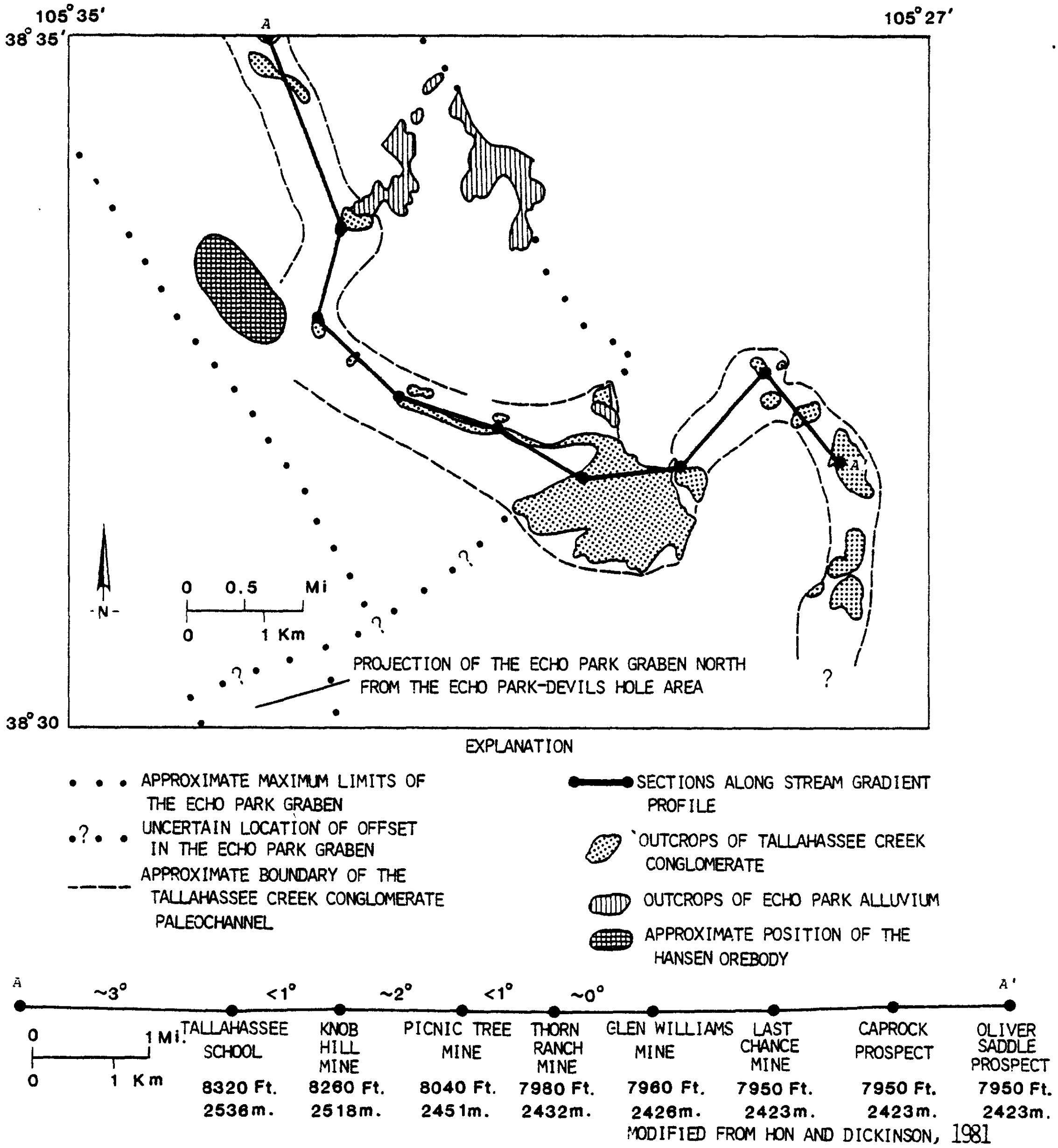

Figure 3.--Map showing the Tallahassee Creek Conglomerate paleochannel, gradient of the paleochannel based on tops of the Tallahassee Creek Conglomerate, and relation of the channel to the approximate location of the Hansen orebody.

is characterized by contorted iron-stained bands. The member contains carbonaceous material and silicified wood. In places, the upper ashy part of the Tallahassee Creek Conglomerate appears to have been intruded diapirically into the overlying laharic sediment of the Thirtynine Mile Andesite.

Orebodies

Shape and distribution.--Few details are presently available about the shape and distribution of the orebodies. According to Cyprus Mining Corporation (1980) "The Hansen orebody is a 'stratiform' uranium deposit that occurs in clayey sandstones, sandy mdustones, and pebble to boulder conglomerates of the lower portions of the Echo Park Formation..." They further state that "the orebody is reduced, but shows alteration of feldspars to clay throughout and is surrounded by oxidizing sediments" and that "It appears that at least some deposition took place in roll-like bodies with uranium enrichment along redox contacts..." Cyprus Mining Corporation identified the ore minerals in the Hansen orebody as uraninite and coffinite (Cyprus Mines Corporation, 1980; Chenoweth, 1980).

Uranium mineralization at the Picnic Tree orebody is primarily in the upper ash fall member of the Tallahassee Creek Conglomerate, which is about 8 m thick at that locality. Little data are available from the Picnic Tree orebody, but some information was obtained from smaller orebodies along the Tallahassee Creek paleo-channel. Uraninite and coffinite are probably the chief primary uranium minerals in the Tallahassee Creek deposits, but meta-autunite was found where the deposits are oxidized (Shappirio and Heinrich, 1961). Orebodies in the Tallahassee Creek are generally tabular in shape, (Chenoweth, 1980; Hon and Dickinson, 1980).

Age of mineralization.--No solid evidence is available to give the age of mineralization, but certain assumptions can be made in this regard. First, it is generally believed that leachable uranium derived from tuffaceous material is more readily leachable shortly after or during deposition. Second, conditions conducive to leaching and concentration of uranium are more likely to have prevailed during dry climatic periods. Two major periods of dry-climate weathering occurred, one in the Oligocene and another at the close of the Pliocene (see below). The age of the rock that is apparently the principal source of uranium, the Wall Mountain Tuff, coincides with the dry climate during the Oligocene Period, and the Oligocene is therefore the most likely age for mineralization. Mineralization in the Echo Park Alluvium during the late Eocene is possible, but only from an Eocene or older source rock.

Geologic controls of mineralization

Uranium source.--The uranium apparently was derived largely from the Wall Mountain Tuff, although younger volcanic units from the Thirtynine Mile volcanic center may have contributed as well. Precambrian granite and granodiorite have lost uranium in the vicinity of the Tallahassee Creek uranium district, but these rocks are not thought to be a primary uranium source for the Tallahassee Creek deposits (Dickinson, unpublished data). Erosion of large amounts of uranium-bearing Precambrian rocks occurred prior to the deposition of the uranium host rocks in the Tallahassee Creek district. In addition, these rocks were probably deeply leached in previous time and uranium liberated by the erosion probably escaped in surface drainage.

Leaching of uranium.--The leaching and dissolution of uranium in the paleo-ground water probably occurred under oxidizing and neutral to alkaline pH conditions. Under these conditions uranium is easily dissolved as a uranyl carbonate. A dry climate may have enhanced the development of these conditions because bases accumulate when not flushed away by rainfall. Alkalinity probably was also raised by the hydration and release of alkali metals from volcanic ash in the sediments. Katayama (1960) discusses the general relationship between uranium deposits and arid climates.

According to MacGinitie (1953) the climate was relatively dry during the Oligocene in the Florissant area about 50 km northeast of the Tallahassee Creek distict. He based his conclusion on the lack of chemical weathering, apparent episodes of desiccation during lacustrine deposition, and fossils from the Oligocene Florissant Lake Beds. In addition, the Oligocene Brule Formation contains bedded gypsum in northwestern Nebraska (Dunham, 1955). The climate was more humid in the Great Plains to the east of the Tallahassee Creek district during much of Miocene and Pliocene (Frye and Leonard, 1957), but it became dry again at the end of Pliocene when caliche soils were developed at the top of the Miocene to Pliocene Ogallala Formation. These upper Pliocene caliches are enriched in uranium in north Texas (Finch, 1975).

Paleohydrologic conditions.--Paleohydrologic conditions in the Echo Park Alluvium were such that oxidizing uranium-bearing waters entered the unit but not in such great quantities as to destroy either the reducing conditions that were important to precipitate the uranium or to destroy the once-formed uranium deposit by oxidation. These conditions were apparently brought about by the lack of an efficient ground-water discharge area at the southeast end of the graben (figs. 3 and 4). A fault extending from the Texas Creek Fault (Taylor and others, 1975) northeastward and under the Thirtynine Mile Andesite (fig. 2) may have limited discharge into the Arkansas River drainage in the southeast. This faulting is covered by the unfaulted lower member of the Thirtynine Mile Andesite, indicating that an efficient discharge has also been lacking since early Oligocene. Artesian pressure in holes drilled into the

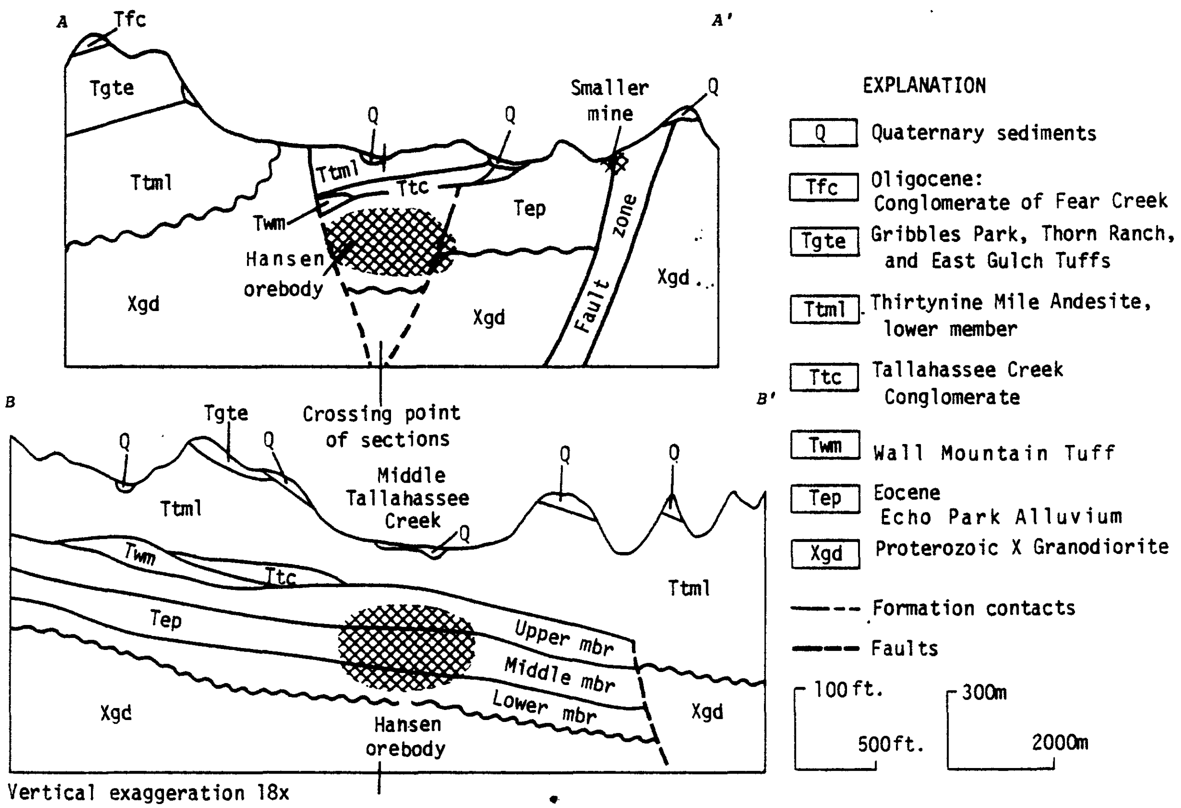

Figure 4.—Speculative cross sections through the Echo Park graben showing the Smaller mine and the hypothetical location of the Hansen orebody (location of cross sections are shown on figure 1).

Echo Park Alluvium (Cyprus Mining Corporation and Wyoming Minerals Corp., 1979) and springs such as Taylor Soda Springs that issue from the Echo Park Alluvium are evidence of the lack of an efficient ground-water discharge area. The present inclination of the top beds of the Tallahassee Creek Conglomerate ranges from zero to 3 degrees to the southeast (Hon and Dickinson, 1980). This suggests that there has not been significant change in attitude of the rocks in the graben since early Oligocene, and that similar hydrologic conditions may have persisted during that time.

When the Wall Mountain covered the Echo Park Alluvium in early Oligocene time, the tuff may have been relatively impermeable, especially in a lower more vitrophyric part. Erosional windows through the tuff during deposition of the Tallahassee Creek Conglomerate may have been important in allowing uranium-bearing ground water into the underlying Echo Park Alluvium. This speculation is suggested by the location of the Hansen orebody on the outside corner of a meander where stream erosion was concentrated in the Tallahassee Creek Conglomerate channel (fig. 3).

Host rocks.--The important characteristics of the host rocks are (1) in the Echo Park graben they are permeable enough to admit uranium-bearing water, (2) they contain impervious beds or facies which limited circulation of oxidizing waters carrying uranium, but which could also destroy the deposit or reductant if circulation had been unrestricted, and (3) they contain a reductant. These characteristics have changed somewhat since sediment deposition. For instance, feldspars have been partly altered in the Echo Park Alluvium and the Wall Mountain Tuff, and ash beds in the top of the Tallahassee Creek Conglomerate and in the lower member of the Thirtynine Mile Andesite have been altered to kaolinite or montmorillonite. Alteration to clay minerals may locally reduce permeability of deposits and may have aided in the preservation of the contained uranium.

Uranium concentration.--Carbonaceous material contained in the host rocks at the time of deposition appears to have been the prime factor in concentration of the uranium. This material, which consisted mostly of wood fragments deposited in a fluvial channel environment but which may also have included carbonaceous paleosols, established and maintained reducing conditions within the host rock. Aerobic metabolism by micro-organisms feeding on the carbonaceous material depleted the oxygen in the sediments. Once the oxygen was depleted around the carbonaceous material, anaerobic sulphate-reducing bacteria produced sulphide ions that combined with iron to form pyrite commonly found associated with the carbonaceous material. The reducing environment precipitated the uranium in a reduced condition generally as uraninite UO_2 or as coffinite $U(SiO_4)_{1-x}(OH)_{4x}$.

Not all of the enrichment can be attributed to the above mechanism, however, because some enrichment is found in relatively pure ash beds or in ash-flow tuff that seems to be free of carbonaceous material. This enrichment may have occurred under oxidizing conditions by absorption of uranium VI in opal (Zielinski, 1980) or iron oxide (Van Der Weijden, 1976), or perhaps it was deposited under reducing conditions produced by dissolved organic matter (humic acids) in the ground water (Granger and others, 1961).

Preservation.--The most important factors in preservation of the deposits are sluggish ground-water movement through the host rock and a large amount of carbonaceous material in the host rock. These two conditions help maintain the reducing conditions in the orebodies and, consequently, the immobility of the uranium. Preservation of the orebodies may be thought of as maintaining the conditions of their formation. Present uranium content of groundwater is as much as 900 ppb (Chenoweth, 1980), suggesting that either the deposits are still forming or they are being destroyed or modified. Present conditions seem to favor uranium deposition, and so the present uranium in the ground water may reflect these conditions. No data on disequilibrium of uranium in the ore or ground water are available to assess this problem.

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