section has N_{207}/N_{235} and N_{206}/N_{238} ratios of approximately 0.127 and 0.0190, respectively, and is equivalent to the concordant age of 123 million years. Assuming an isotopic composition of the contaminating common lead similar to the Nesquehoning galena plus original radiogenic lead, concordant ages of 115 and 135 million years are obtained for Penn Haven Junction and Mount Pisgah, respectively. Maximum ages of source rock providing the old radiogenic lead range from approximately 350 to 475 million years.

The limitations imposed both by the number of samples available and the analytical data do not justify any emphasis on an exact age solution. However, the conclusion that both Carbon County uranium occurrences were formed near the end of the Jurassic or early in the Cretaceous would appear to be mathematically and geologically sound.

REFERENCES

Genth, F. A., 1875, Preliminary report on the mineralogy of Pennsylvania: Pennsylvania Geol. Survey, 2d, B, p. 144.

Holmes, Arthur, 1960, A revised geological time-scale: Edinburgh Geol. Soc. Trans., v. 17, p. 183–216.

Klemic, Harry, and Baker, R. C., 1954, Occurrences of uranium in Carbon County, Pennsylvania: U.S. Geol. Survey Circ. 350, 8 p.

Kulp, J. L., 1959, Geological time scale (abs.): Geol. Soc. America Bull., v. 70, p. 1634.

Stieff, L. R., and Stern, T. W., Graphic and algebraic solutions of the discordant lead-uranium age problem: Geochim. et Cosmochim. Acta (in press).

Stieff, L. R., Stern, T. W., Oshiro, Seiki, and Senftle, F. E., 1959, Tables for the calculation of lead isotope ages: U.S. Geol. Survey Prof. Paper 334–A, 40 p.

Wherry, E. T., 1912, A new occurrence of carnotite: Am. Jour. Sci., 4th ser., v. 33, p. 574–580.

Willard, B., 1935, Portage group in Pennsylvania: Geol. Soc. America Bull., v. 46, p. 1195–1218.

24. URANIUM AT PALANGANA SALT DOME, DUVAL COUNTY, TEXAS

By Alice D. Weeks and D. Hoyle Eargle, Washington, D.C., and Austin, Tex.

Work done in cooperation with the U.S. Atomic Energy Commission

One of the most unusual uranium deposits discovered in recent years is in Pliocene sediments above the caprock of Palangana salt dome, in Duval County, Texas. Palangana is in the Coastal Plain, about 70 miles west of the Gulf of Mexico and 100 miles north of the Rio Grande. The salt dome was discovered in 1916; sulfur was produced from the caprock in the 1920's and early 1930's, and during the same period a few thousand barrels of oil was produced from shallow sands above the caprock (Barton, 1925). At present brine is being produced by the Columbia Southern Chemical Company, and it was this company that discovered the uranium by gamma-ray logging of holes drilled in a search for potassium.

The surface expression of Palangana salt dome is a shallow basin in a brush-covered plain that slopes eastward about 20 feet per mile and is capped with a nearly continuous layer of caliche. The dome is covered by the Goliad sand (Pliocene), which dips 25 to 40 feet per mile east-southeastward and overlaps middle Tertiary rocks (Sayre, 1937) (fig. 24.1). The Goliad sand overlaps unconformably on the Lagarto clay (Miocene?), which is dominantly an impervious clay with a few sand lenses, on the Oakville sandstone (Miocene) a massive sand with some gravel, clay balls and ashy clay, and on the Catahoula tuff (Miocene?), which contains highly tuffaceous sand and clay and volcanic conglomerate (Sayre, 1937), and on the Frio clay (Oligocene?), which is dominantly clay and relatively impermeable.

Most of the Tertiary sediments, but especially the Catahoula tuff, contain large quantities of volcanic detritus, pebbles, sand grains of igneous minerals, and shards of glass. The most abundant rock types are chiefly andesite, trachyandesite, and soda trachyte (Bailey, 1926). The outcropping rocks of the Catahoula are slightly to considerably altered by alkaline ground water, which caused the development of a caliche cover, opal, and chalcedony cements, and formation of zeolites. The most likely sources of the Catahoula sediments appear to be the igneous rocks of Mexico, 100 miles or more to the west, or those of the Big Bend country, 300 miles northwest. Recent analyses of a suite of the Big Bend rocks indicate they contain more than average quantities of uranium (David Gottfried, written communication, 1959).

The salt of the Palangana dome is 850 to 1,000 feet below the surface (fig. 24.1). It is capped by anhydrite, gypsum, sulfur, and carbonate rock several hun-

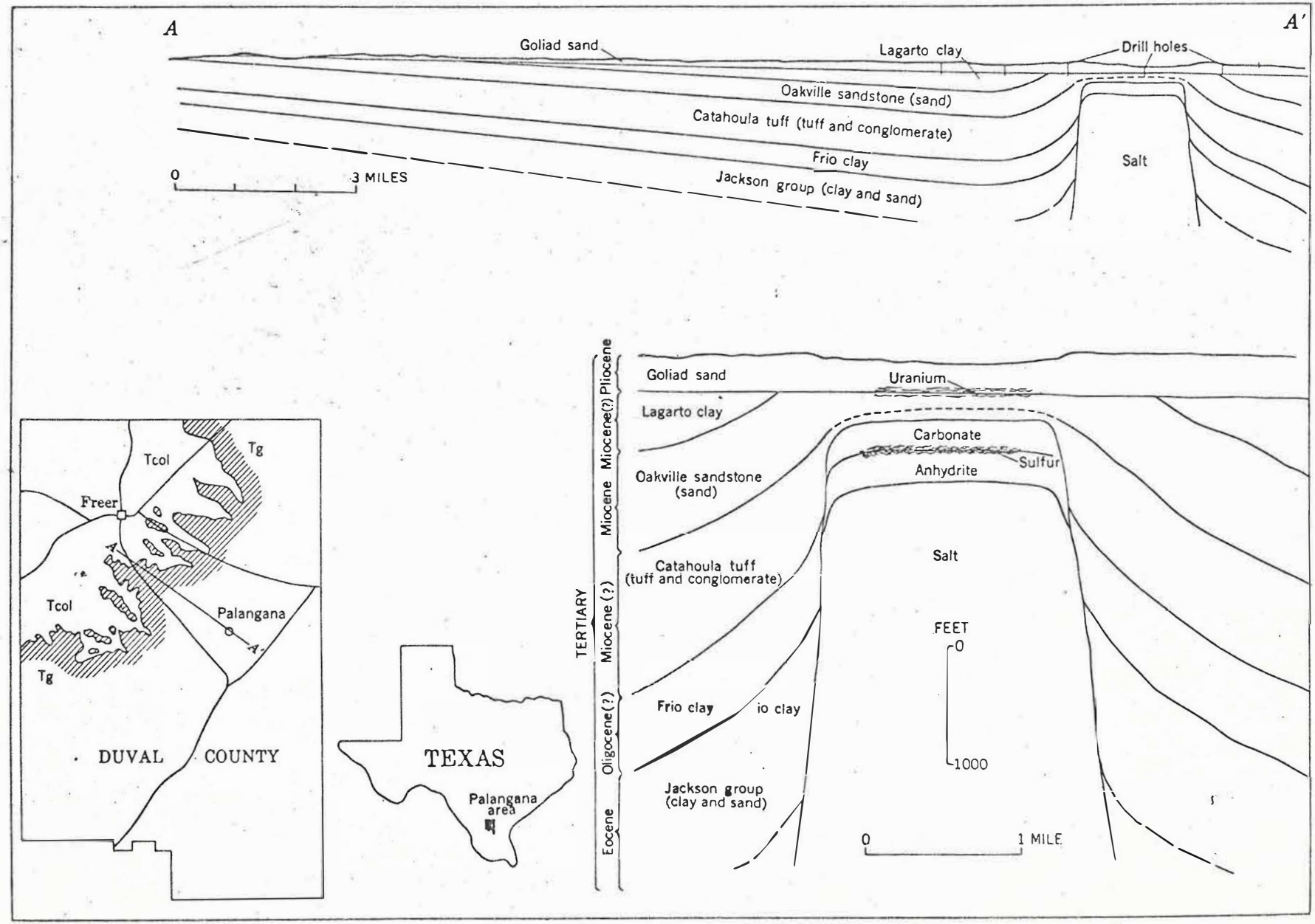

FIGURE 24.1.—Diagrammatic cross sections of Palangana salt dome and of the area between Freer and Palangana, Duval County, Tex.

dred feet in total thickness. The uranium ore, chiefly very fine divided sooty pitchblende, occurs at a depth of about 325 feet, more than 100 feet above the caprock. It is in highly calcareous clay-ball conglomerate interbedded with friable fine- to medium-grained sand locally impregnated with a little oil. Only a few beds are firmly cemented. The conglomerate contains black chert pebbles, nodular authigenic chalcedony, a little partly silicified fossil wood, and a few vertebrate fossils. Several horse teeth and a dog tooth found by company personnel and by us were identified by Prof. J. A. Wilson, of the University of Texas, as belonging to the fauna of the basal member of the Goliad sand.

The electric and the lithologic logs of drill holes on the dome have been correlated with those of drill holes a few miles northwest of the dome. The logs were correlated by means of clay-ball conglomerate at the base of the Goliad. The deepest core which we examined was 460 feet deep and on the dome. The sediments above the conglomerate show minor variations, but they consist mainly of moderately to very fine grained silty sandstone or sandy clay and are all at least slightly calcareous. The differences between the cores are in the rocks below the conglomerate and in the color of the ore zone. Over the salt dome between depths of about 276 and 460 feet the rocks within the ore zone as well as those in the first 50 feet above it and those below it are greenish gray, whereas off the dome correlative rocks are pinkish to yellowish gray. This color and the fine-grained disseminated pyrite in the ore zone and under it are due to the reducing environment of the H_2S emanating from the caprock. The sand under the ore zone contains reworked foraminifera and is believed to be Oakville sandstone. The Lagarto clay is not present on or close to the dome.

In March 1959 a suite of samples was collected along

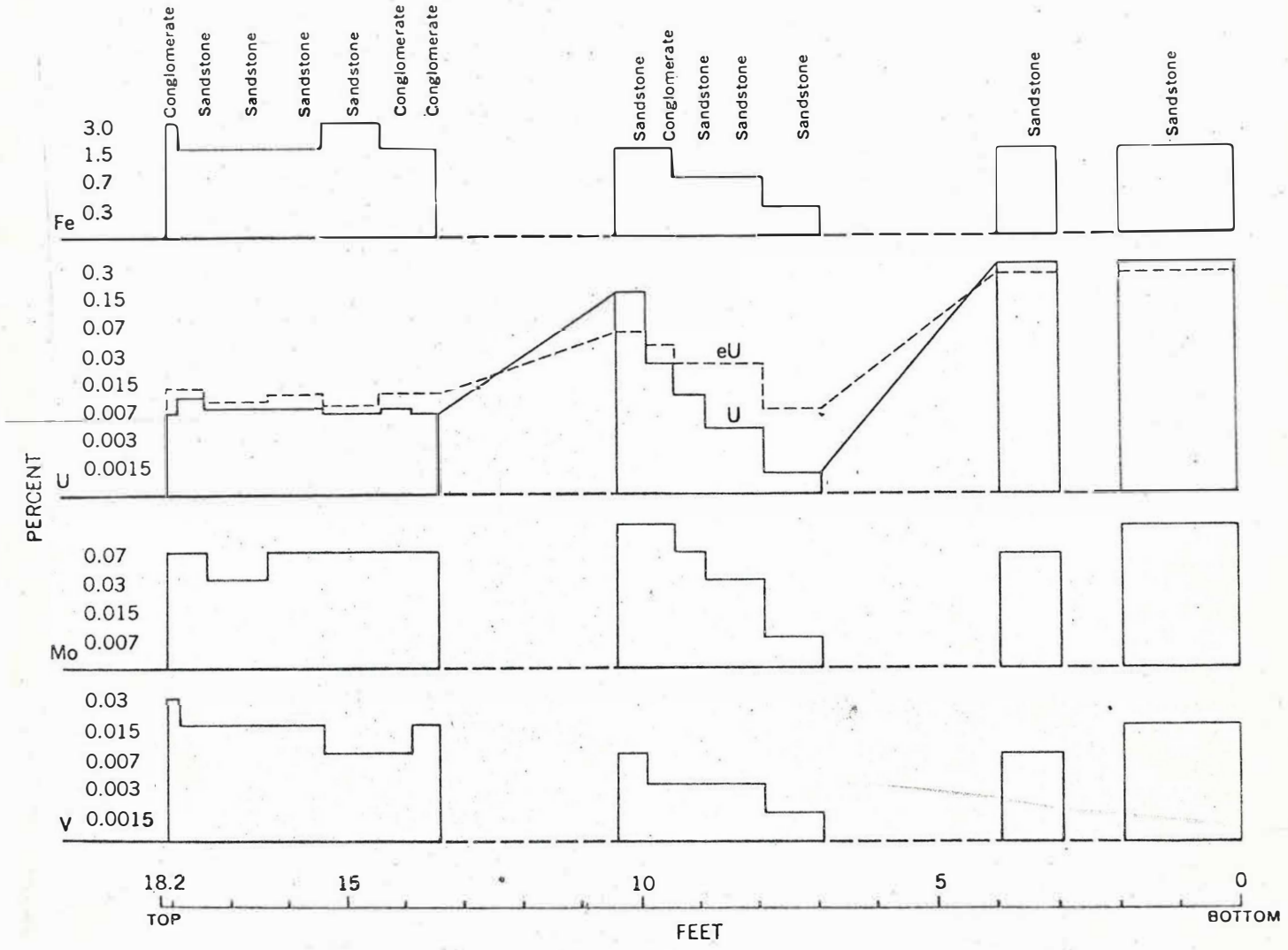

FIGURE 24.2.—Graph of selected data from radiometric, chemical, and semiquantitative spectrographic analyses of suite of samples through the ore zone at Palangana.

a vertical section through the ore zone in the small prospect mine. The rocks contain much water, are at a temperature of about 90° to 100° F, and give off considerable H_2S. Spectrographic and chemical analyses of the samples show that concentrations of the easily oxidizable and reducible elements iron, uranium, molybdenum, and vanadium are directly correlated (fig. 24.2). The ore zone contains several hundred times as much uranium as average sandstone, about 75 times as much molybdenum, and about 5 times as much vanadium. Molybdenum and vanadium though much less abundant than uranium are present in amounts that are significant when one considers that these elements commonly accompany uranium in the Colorado Plateau (Garrels and others, 1957). The carbonate content (percentage of acid-soluble fraction) ranges from 17 to 37 percent; the highest is in the firmly cemented sandstone 12 feet from the bottom in this suite.

The equivalent uranium of these samples differs considerably from the actual uranium content. Radiochemical analyses by J. R. Rosholt, Jr., show the nature of the disequilibrium (fig. 24.3). If the uranium and its daughter products were in perfect equilibrium, all the ratios would be 1 and would be represented by a horizontal line. The graph shows, however, that the three samples of ore grade are all low in radioactivity, and the six samples below ore grade high in radioactivity, as compared with uranium content determined chemically. The amount of radium in these samples is quite variable, and it is uncertain whether radium was added or uranium extracted from any particular sample. Migration is obviously taking place in this

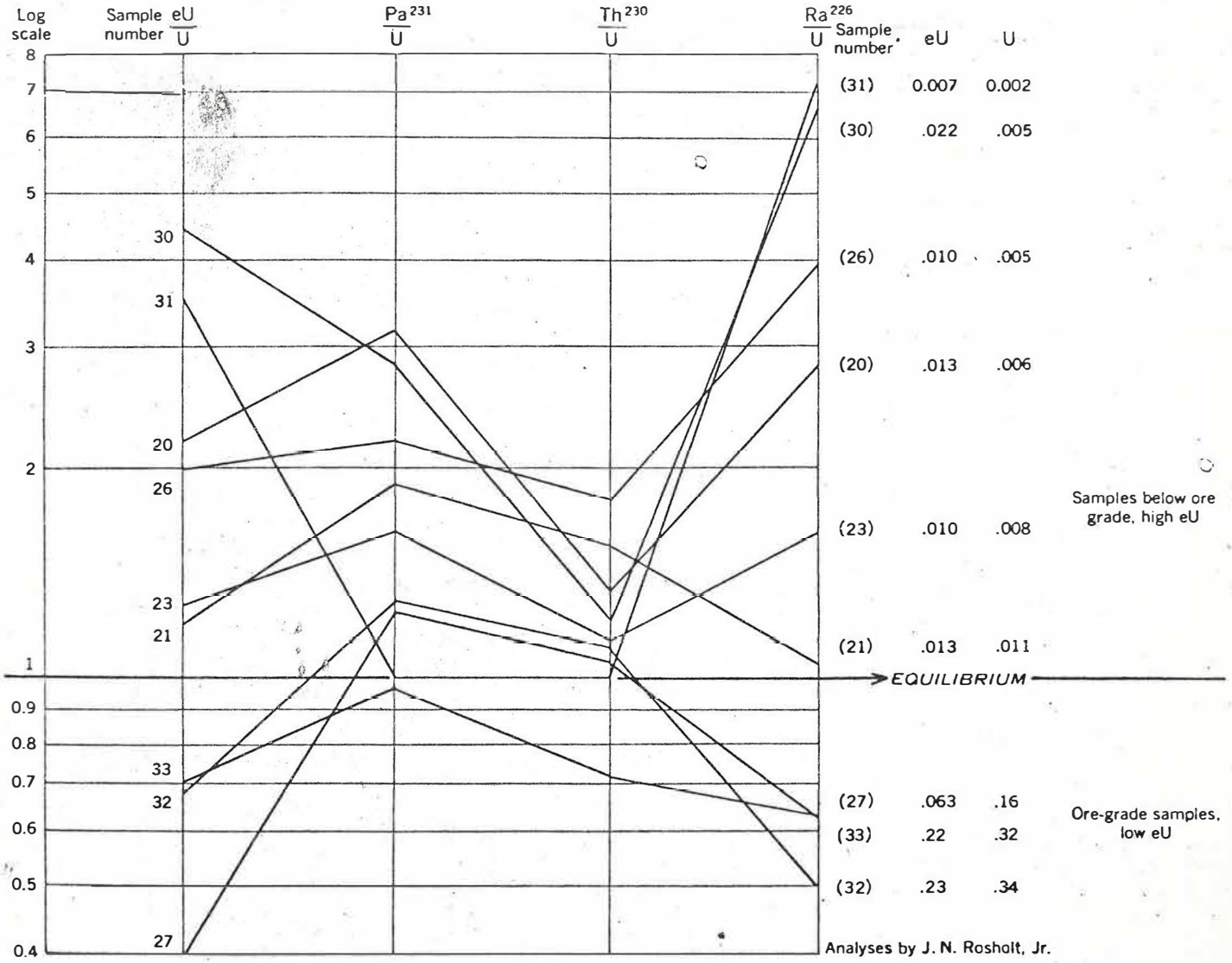

FIGURE 24.3.—Graph of ratios of uranium daughter products to uranium, showing nature of radioactive disequilibrium for suite of samples at Palanganna (same suite as in fig. 24.2).

deposit, and in spite of moderately reducing conditions the uranium is not very firmly fixed.

We believe that uranium was leached by alkaline carbonate water from the volcanic material in the Tertiary sediments, chiefly from the Catahoula tuff but possibly in part from other rocks that contain a smaller proportion of volcanic debris. This is highly reasonable because (a) of the large volume of volcanic detritus that contains above average uranium, (b) the sediments consisted of highly reactive or unstable material in a terrestrial deposit, (c) the climate was hot, and so dry that leached products would remain in more concentrated solution than in humid climates. A consistent geochemical environment is indicated by the extensive caliche cap, the presence of highly mineralized ground water, the widespread occurrence of opal and chalcedony, the presence of many small concentrations of uranium in surface outcrops of the tuffaceous rocks, and by the zeolitic alteration of those rocks. Some of the uranyl carbonate in solution probably migrated downdip in permeable beds confined between less permeable clay beds until it reached the reducing environment of the salt dome. The precipitated uranium is very fine grained and disseminated; this fact as well as the radiochemical relationships indicates that the deposit is very young and unstable, and that it probably is still in the process of formation or modification.

REFERENCES

Bailey, T. L., 1926, The Gueydan, a new middle Tertiary formation from the southwestern coastal plain of Texas: Univ. Texas Bull. 2645, 187 p.

Barton, D. C., 1925, Salt domes of South Texas: Am. Assoc. Petroleum Geologists Bull., v. 9, p. 536–589.

Garrels, R. M., Hostetler, P. B., Christ, C. L., and Weeks, A. D., 1957, Stability of uranium, vanadium, copper, and molybdenum minerals in natural waters at low temperatures and pressures [abs.]: Geol. Soc. America Bull., v. 70, p. 1127–1184.

Sayre, A. N., 1937, Geology and ground-water resources of Duval County, Texas: U.S. Geol. Survey Water-Supply Paper 776, 116 p.

25. PARAGENESIS OF URANIUM ORES IN TODILTO LIMESTONE NEAR GRANTS, NEW MEXICO

By Alfred H. Truesdell and Alice D. Weeks, Washington, D.C.

Work done in cooperation with the U.S. Atomic Energy Commission

The Todilto limestone is locally replaced by minerals of uranium and vanadium, and to a lesser extent by minerals of fluorine, iron, lead, manganese, molybdenum, and selenium. The replacement started along grain boundaries, especially where the grains were dissimilar—for instance, along the borders of detrital quartz or feldspar, between coarse- and fine-grained calcite, or around carbonaceous masses. The uraninite was initially deposited as colloform coatings from which it expanded in rounded shapes into adjoining fine-grained calcite. The colloform bodies tended to coalesce, and in places they replaced the rock almost completely, leaving only relict quartz grains.

The ore can be loosely classified into three types: uranium ore, uranium-fluorine ore, and uranium-vanadium ore (fig. 25.1).

The simplest type is uranium ore containing no appreciable quantity of vanadium or fluorine. This occurs partly in separate deposits and partly within deposits containing irregularly distributed vanadium minerals. Polished sections show that some pyrite was formed before uraninite and coffinite and was strongly corroded by those minerals. Colloform uraninite replaced the limestone, starting along grain boundaries and finally replacing the grains themselves. Detrital grains commonly served as nucleating centers, as did boundaries between coarsely crystallized light-colored calcite and their finer grained limestone matrix; ore formed on these boundaries commonly extends into and replaces the limestone.

Later, coffinite coated the uraninite and filled shrinkage cracks that developed within it. The last-deposited uranium was in a fine-grained intergrowth of calcite and uraninite. Euhedral galena crystals were deposited at the same time as the uraninite and coffinite and have been partially replaced by calcite. In a few specimens the ore has been shattered and the fractures filled with late calcite. Late pyrite is also found in some polished sections; it replaces detrital grains, starting along their boundaries, and may surround the uraninite border of a grain.