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Annotated Bibliography of Grants Uranium Region, New Mexico, 1950 to 1972

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Preface

This bibliography lists selected papers pertaining to the geology of the Grants uranium region (see definition by Laverty and others, 1963, fig. 1).

The work comprises a *bibliography* (pages 5-62) of 319 citations with annotations and a *subject index* (pages 63-69). Citations are listed in alphabetical and numerical order. An annotation, in smaller type, follows each citation. If the publication has illustrations, they are included as part of the annotation. The *index* has 10 main categories, several of which are further divided; an explanation appears at the beginning of the index.

This bibliography treats material published during the period 1950 to 1972. A few pre-1950 studies are included because of their pertinence to regional geology. For early studies of uranium geology, refer to the bibliographies of Cooper (1953), Melin (1957), and McKelvey (1955) in "Search for uranium in the United States." Generally excluded are dissertations and open-file reports. Trace-element studies of the U.S. Geological Survey are excluded because these reports are not intended for general use.

Criteria used for selecting publications for this bibliography are: 1) specific application to the geology of the Grants uranium region, and 2) relevance to uranium mineralization of the region. Ordinarily, publications were excluded if they did not cover features of relations of the region or the immediate neighboring areas. For example: a study of Morrison Formation is included because of specific mention of the formation in the region; a study of distribution of elements in uranium host rocks of the Colorado Plateau is included because of specific mention of Grants localities or relations; and publications of laboratory investigations are included where some of the analyzed samples were obtained from the Grants region.

For additional information on traditional geologic subjects, one should consult other bibliographies of the geology of New Mexico.

ACKNOWLEDGMENTS—The writer is indebted to Grants Public Library for obtaining most of the papers described herein. Many had to be xeroxed before the library could get them. Thanks are extended also to members of the Grants office of the U.S. Atomic Energy Commission—especially Harlan K. Holen and Luther L. Smith—for making their library available to the author and for taking the time to review the manuscript. Gratitude is expressed also to John B. Squyres, Arthur P. Butler, Jr., Reuben J. Ross, Jr., and Jocelyn E. Cox for their help. The writer acknowledges use of language of authors of papers in describing contents of their publications. This could not always be done by simply using quotation marks. Grace Exploration contributed facilities for duplicating the original manuscript.

Grants, N.M.
February, 1974

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Annotated Bibliography

1 Abbiss, H. J., 1963, Mine safety problems: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 264-267.

Work of the Uranium Operations Safety Council in Grants uranium region. Subjects include objectives of the council, safety rules, and effectiveness of rules.

Illustrations: graphs; table of safety data.

2 Abdel-Gaward, A. M., and Kerr, P. F., 1961, Urano-organic mineral association: Am. Mineralogist, v. 46, p. 402-419.

Studies urano-organic mineral association pertinent to genesis of uranium deposits on the Colorado Plateau. Localities of analyzed samples include uranium deposits of Grants uranium region, especially the Jackpile mine of the eastern part. Objectives are twofold: "(1) to study the effect of heat on semifluid asphalt collected from fissure seepages in certain uranium deposits in order to compare the heat-treated material with naturally occurring uranium-bearing *asphaltite* from the same area, and (2) to study the association of coffinite, a frequent accompaniment of *asphaltite*, in order to obtain more information on the nature of this unusual mineral and the significant association involved." Authors remark that "the intimate and widespread association of indurated uranium-bearing asphaltite and the uranium silicate coffinite suggests that the two were formed contemporaneously." They also believe a hydrothermal origin prevails for both. The question of origin is approached chiefly through considering the temperature range under which coffinite forms and the temperature of induration of asphaltite as indications of the temperature prevailing during uranium mineralization on the Colorado Plateau. Subjects treated appear under the following headings: indurated uranium-bearing asphaltite; infrared absorption of uranium-bearing asphaltite; the uranium asphaltite-coffinite association; the separation of coffinite; X-ray data on coffinite; thermal behavior of uranium asphaltite and coffinite; X-ray data on heated samples; loss of weight and change in color; infrared absorption of heat treated samples; optical observations; electron micrographs.

Illustrations: infrared absorption curves; tables of X-ray diffraction analyses; table of X-ray spectrographic analyses; D.T.A. curves; graph of heat effects on weight and color of coffinite; tracing from electron photomicrographs of crystal outlines of coffinite aggregates from the Jackpile mine (Grants uranium region).

3 Adler, H. H., 1963, Concepts of genesis of sandstone-type uranium ore deposits: Econ. Geology, v. 58, p. 839-852.

Genesis of uranium deposits of the western United States in connection with developing models of uranium distribution for use in exploration. Purpose is the present background—concepts and data—for construction of these models. Deposits of Grants uranium region are included. Subjects occur under following headings: unoxidized sandstone-type uranium ores; cyclic accretion of uranium in sediments; magmatic hydrothermal and fracture-controlled uranium ores; breccia-pipe deposits; and salt-dome deposits.

Illustrations: chart of ratios of hydrogen sulfide gas, petroleum, and sulfide and sulfate minerals from various sources; chart of minerals from magmatic and ground-water hydrothermal mineral deposits.

4 Akers, J. P., and others, 1958, Moenkopi and Chinle Formations of Black Mesa and adjacent areas: *in* New Mexico Geol. Soc. Guidebook 9th Field Conf., Black Mesa basin, northeastern Arizona, p. 88-94.

Stratigraphic study of Moenkopi and Chinle Formations of northeastern Arizona. The work overlaps some into the westernmost part of Grants uranium region, and illustrations portray the thickness of Chinle in the region and extend members of Moenkopi and Chinle into the area.

Illustrations: fence diagram of Moenkopi and Chinle Formations; isopach map of Chinle Formation.

5 Allen, J. E., and Balk, Robert, 1954, Mineral resources of Fort Defiance and Tohatchi quadrangles, Arizona and New Mexico: New Mexico Bureau Mines Mineral Resources Bull. 36, 192 p.

Describes general geology of two 15-minute quadrangles located on an east-west line that crosses the Arizona-New Mexico border. South boundary of the area lies approximately 16 miles north of Gallup; the area adjoins Grants uranium region on the west and north. Line of

mapping crosses Defiance uplift. Subjects include stratigraphy, structure, igneous geology, geomorphology, sedimentary petrology, and mineral resources and ground water.

Illustrations: geologic map of the two quadrangles (1/48,000); geologic sections; location maps; sketches; photographs; photomicrographs; structure contour maps; correlations of stratigraphic sections; representations of petrologic data; diagrammatic sections of stratigraphic relations; measured stratigraphic sections; tables of data and analyses.

6 Anderson, E. C., 1955, Occurrences of uranium ores in New Mexico: New Mexico Bureau Mines Mineral Resources Circ. 29, 38 p.

Information—chiefly tabulated—pertaining to uranium prospects in New Mexico, including Grants uranium region. Items include location of deposits; lithology of host rock; name of host formation; and names, owners, leases, and mine classifications. Also sections describing requirements for staking uranium claims, describing uranium minerals identified in New Mexico, describing ore guides, and giving general information useful to prospectors.

Illustrations: location map of uranium mines and prospects.

7 Anderson, E. C., 1957, The metal resources of New Mexico and their economic features through 1954: New Mexico Bureau Mines Mineral Resources Bull. 39, 183 p.

Briefly describes all known metal deposits of the state other than those of iron and manganese and summarizes history, production, and geology of the various districts. Uranium is described under occurrence and distribution of New Mexico ore minerals; mining districts, including McKinley and Valencia Counties, as subheadings; and uranium, including discovery and development of ore bodies, geologic horizons favorable to discovery, uranium minerals, and review by counties as subheadings. Briefly mentions mineralization of Grants uranium region.

Illustrations: tables and other representations of production; small-scale maps.

8 Anderson, R. Y., and Kirkland, D. W., 1960, Origin, varves, and cycles of the Jurassic Todilto Formation, New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 44, p. 37-52.

Petrologic study of Todilto Formation of northwestern New Mexico, including Grants uranium region. Descriptions include stratigraphy—sketch of Todilto and adjacent formations; lithology of limestone member (Todilto) microstratigraphy (variety, distribution, and thickness of laminae comprising rock), and petrograph of individual classes of laminae (texture and composition); and lithology of gypsum member (Todilto) treated as the limestone. Genesis of the formation includes environment of deposition—marine or nonmarine—and such particulars as bottom conditions and temporal variations in the chemical and physical nature of the environment; source of salts; and time required for deposition of the formation. Origin of the temporal variations in environment, especially the possibility of alterations in climate, seasonal and long-term, is considered.

Illustrations: photomicrographs; small-scale paleogeographic map; graph of variations of thickness of Todilto varves with time; diagrammatic illustration of the varved clastic-organic-evaporite cycle applied to Todilto Formation; chart of relation between varved clastic-organic-evaporite cycles in general and other depositional cycles.

9 Anderson, R. Y., and Kirkland, D. W., 1966, Intrabasin varve correlation: Geol. Soc. America Bull., v. 77, p. 241-255.

Studies lateral variation of laminations in varved sequences. Formations include Pleistocene Rita Blanca Lake Beds, Jurassic Todilto Formation, Permian Castile Formation, and Permian Zechstein Formation. Todilto Formation is part of the Jurassic section of Grants uranium region. Description of Todilto Limestone (lower member of Todilto Formation) includes lithology of the limestone, continuity of laminations in the limestone, lateral variations in the laminations, correlations of units of laminations, and particulars of the depositional environment.

Illustrations: photomicrographs; locality maps; representations of analyses pertaining to correlation of units.

10 Ash, S. R., 1967, The Chinle (Upper Triassic) megaflora of the Zuni Mountains, New Mexico: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 125-131.

Describes megaflora of Chinle Formation of Zuni Mountains, southern bordering area of the western part of Grants uranium region. Includes age and correlation of Chinle and climate of the area during deposition.

Illustrations: photographs and sketches of fossils.

11 Austin, S. R., 1960, Alteration at Ambrosia Lake, New Mexico: U.S. Atomic Energy Comm. RME-134, 19 p.

Republished in 1963 as Alteration of Morrison sandstone; *see* Austin, 1963 (below).

12 Austin, S. R., 1963, Alteration of Morrison sandstone: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 38-44.

Petrologic study of alteration of Morrison sandstones of Grants uranium region. Two periods of alteration are evident: early, alteration under reducing conditions; later, alteration under oxidizing conditions. Chief purpose is to consider the alteration that took place under reducing conditions, because the uranium ore is largely confined to the unoxidized zones. Describes products of the early alteration: identity of minerals formed, effects on minerals of prealteration origin, and form and manner of occurrence of authigenic minerals. Includes nature of original sediment (original mineral composition); character of altering fluids (pH and Eh of solutions), composition of fluids, and origin of fluids; paragenesis (paragenetic relations of minerals and temporal relation of alteration to uranium deposition); and genesis of deposits (relation of alteration to uranium deposition, and, especially, the coincidence that two rare items occur in the same locality: large uranium deposits and widespread alteration of the type described).

Illustrations: photomicrographs.

13 Barrs, D. L., 1961, Permian blanket sandstones of Colorado Plateau: *in* Am. Assoc. Petroleum Geologists, Geometry of sandstone bodies, Tulsa, Oklahoma, p. 179-207.

Stratigraphic study of Permian formations of the Colorado Plateau, including bordering areas (Zuni Mountains) of Grants uranium region. Subjects include regional correlations; Cedar Mesa Sandstone—lateral relationships, bedding characteristics, and depositional environments; De Chelly Sandstone—regional distribution, bedding characteristics, and depositional environments; Coconino-Glorieta Sandstone—distribution, bedding characteristics, and depositional environments; and comparison and conclusions.

Illustrations: stratigraphic correlation chart; fence diagram; isopach maps; diagrammatic, geologic sections; diagrammatic representations of inclination and direction of dip of cross stratification; photographs.

14 Baars, D. L., 1962, Permian System of Colorado Plateau: Am. Assoc. Petroleum Geologists Bull., v. 46, p. 149-218.

Comprehensive stratigraphic study of Permian rocks of the Colorado Plateau including Grants uranium region. Permian rocks of the Plateau have been the least understood of the Plateau section and determining their basic stratigraphy is the purpose of the investigations. Study includes the use of 650 measured sections (outcrop) and logs of 740 well sections. Subjects include history of stratigraphic terminology; terminology of this paper; nature of Permian-Pennsylvanian boundary; Cutler Group; Cutler Group undifferentiated; Lower Cutler equivalents; post-Cutler Permian rocks—Yeso Formation, Coconino-Glorieta Sandstone, Toroweap-Kaibab-San Andres correlations; Permian-Triassic unconformity; paleogeography; and climate.

Illustrations: isopach maps; stratigraphic cross sections; stratigraphic chart; fence diagram; measured sections.

15 Baker, I., and Ridley, W. I., 1970, Field evidence and K, Rb, Sr data bearing on the origin of the Mt. Taylor volcanic field, New Mexico, U.S.A.: Earth and Planetary Sci. Letters, v. 10, p. 106-114.

Studies stratigraphy and geochemistry of Mt. Taylor volcanic field of the central and eastern parts of Grants uranium region. Subjects include regional setting; volcanic history—distribution, general lithology, stratigraphy, and age of volcanics; compositional variations of the volcanic rocks; K, Rb, Sr data; discussion—origin of the volcanics.

Illustrations: schematic chart of stratigraphy of the volcanic field; graphic diagrams of compositional variations of the volcanics; tables of analyses.

16 Ballmer, W. E., 1963, Growth and production: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 270-271.

History of growth of the uranium industry in Grants uranium region 1950-1962.

Illustrations: tables of production data.

17 Barnes, F. C., and Arnold, Emery, 1951, Proved and potential oil and gas traps of the San Juan basin: *in* New Mexico Geol. Soc. Guidebook 2nd Field Conf., South and west sides of the San Juan basin, New Mexico and Arizona, p. 132-140.

Has large-scale, structure contour map of Hospah anticline, located in an area bordering the north central part of Grants uranium region.

18 Bassett, W. A., and others, 1963, Potassium-argon ages of volcanic rocks near Grants, New Mexico: Geol. Soc. America Bull., v. 74, p. 221-225. Also 1963, Geology and technology of the Grants uranium region: New Mexico Bureau Mines Mineral Resources Mem. 15, p. 214-216.

Determinations of absolute age of volcanic rocks of Mt. Taylor field cropping out near Grants, central part of Grants uranium region, especially the age of volcanics on Grants Mesa. Report an age of 3.3 ± 0.3 m.y. for samples from ash below the lava caps on Grants Mesa and La Jara Mesa. Suggest that at least part of the volcanism of Mt. Taylor itself is the same age or younger. Subjects include geologic setting (the F-33 mine, a Todilto uranium deposit); local stratigraphy of volcanics; techniques of analysis.

Illustrations: geologic sketches.

19 Beaumont, E. C., and others, 1956, Revised nomenclature of Mesaverde Group in San Juan basin, New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2149-2162.

Describes stratigraphy of the Mesaverde Group in San Juan basin, including Grants uranium region. Subjects include nomenclature of northwestern part of San Juan basin; nomenclature of southern and eastern parts of San Juan basin; reconciliation of northern and southern nomenclature of lower part of Mesaverde Group; relations and nomenclature of Cliff House Sandstone; Tohachi Formation.

Illustrations: map of distribution of divisions of Mesaverde Group; diagrammatic section of stratigraphic relations in Mesaverde Group.

20 Beaumont, E. C., and O'Sullivan, R. B., 1957, Geologic map of the Satan Pass-Thoreau area, McKinley County, New Mexico: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin (in pocket).

Small-scale (2 miles/inch) geologic map of a strip—approximately 10 miles wide (E-W) and 25 miles long (N-S)—in the western half of Grants uranium region. As a coordinate for location, Thoreau is located in the SW corner of the map. Mapped rocks include formations of the section, Chinle (Triassic)-Menefee (Cretaceous), inclusive, and unconformably overlying basalts of Quaternary age.

21 Bell, K. G., 1956, Uranium in precipitates and evaporites: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 381-386.

Reviews distribution of uranium in precipitates and evaporites. Subjects include uranium in carbonate rocks; uranium in phosphatic sediments; uranium in evaporites; uranium in caliche-type deposits; and uranium in siliceous precipitates. Occurrences of uranium in Todilto Limestone of Grants uranium region (mineral assemblages, characteristics of the limestone, and possible origin of the uranium are mentioned).

Illustrations: table of uranium content of various limestones.

22 Bell, K. G., 1960a, Uranium and other trace elements in petroleums and rock asphalts: U.S. Geol. Survey Prof. Paper 356-B, p. 45-65.

Studies uranium and other trace elements in petroleums and rock asphalts. Subjects include distribution of uranium in petroleums and natural asphalts; significance of uranium content of petroliferous substances; source of uranium; mode of occurrence of uranium; hypothetical role of petroleums in the genesis of uranium deposits in sedimentary rocks; uraniferous organic substances called asphaltite; petroleums and rock asphalts as source materials for uranium.

Illustrations: tables of distribution and content of uranium and other trace metals in ash of crude oils and rock asphalts.

23 Bell, K. G., 1960b, Deposition of uranium in salt-pan basins; *in* U.S. Geol. Survey Prof. Paper 354-G, Short papers, p. 161-169.

Studies sedimentation in salt-pan basins with regard to the distribution and occurrence of uranium.

Illustrations: tables of composition of sediments.

24 Bell, K. G., 1963, Uranium in carbonate rocks: U.S. Geol. Survey Prof. Paper 474-A, 29 p.

Origin of uranium in commercial amounts in carbonate sediments and rocks. Studies deposits in Todilto Limestone of Grants uranium region. Subjects include carbonate sediments, varieties and genesis; uranium in modern carbonate sediments, distribution and origin; syngenetic uranium in carbonate rocks, distribution and origin; transporting solutions of epigenetic uranium, chemical particulars; epigenetic uranium deposits in carbonate rocks, classification and description of kinds of deposits and genesis of classes of deposits. Todilto subjects include stratigraphic and sedimentologic particulars of the Todilto; types of deformation influencing the Todilto; distribution of mineralization; genesis of deposits (source of uranium, trapping mechanisms, and chemical environment of deposition).

Illustrations: tables showing chemical composition, mineral composition, and general lithology samples of carbonate rock.

25 Berglof, W. R., and Wampler, J. M., 1965, Isotopic study of uraninite from the Todilto Limestone, Grants, New Mexico (abs.): Am. Geophys. Union Trans., v. 46, p. 164.

Authors' abstract: "Isotopic ages have been obtained for eight uraninite samples from the *Colorado Plateau type* uranium deposits of the upper Jurassic Todilto Limestone near Grants, New Mexico. Close agreement between the uranium-lead ages of four samples indicates an age of 150-155 m.y. for the uraninite mineralization. The Jurassic-Cretaceous boundary is well dated at about 135 m.y. Geologic evidence precludes strict syngenesis, but uranium was apparently emplaced shortly after deposition, probably during diagenesis. The isotopic ages for one sample are concordant. All but one of the remaining samples show a consistent pattern of discordance, which may be attributed to lead loss of Pb^{206}. Leaching experiments demonstrate that Pb^{206} may be preferentially removed from uraninite under laboratory conditions. Mass spectometric determinations of U^{234}/U^{238} ratios for several uraninites indicates no significant present day uranium isotopic disequilibrium, unlike that demonstrated for some other Plateau rock and ore samples. Pb^{210}/Pb^{206} ages have been determined and agree generally with U^{238}/Pb^{206} ages."

26 Birdseye, H. S., 1957, The relation of the Ambrosia Lake uranium deposits to a pre-existing oil pool: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 26-29.

Genesis of Morrison uranium deposits of Ambrosia Lake district, central part of Grants uranium region. Reviews local structure; local stratigraphy, especially Morrison; and distribution of mineralization with respect to organic matter, structural features, and stratigraphic position. Considers function of the organic matter closely associated with the mineralization in ore-forming processes; origin of the organic matter, the genetic connection of the organic matter and an inferred, previously existing, oil pool, and geologic events influencing the pool and adjoining areas; and the source of uranium.

Illustrations: small-scale, structure-contour map of Ambrosia Lake area (from Young and Ealy, 1956) with ore bodies, oil pool and arrows (denoting presumed path of migrating oil) plotted by H. S. Birdseye; small-scale, surface, geologic map of Ambrosia Lake area (from Young and Ealy, 1956).

27 Bozanic, Dan, 1955, A brief discussion on the subsurface Cretaceous rocks of the San Juan basin: *in* Four Corners Geol. Soc. Guidebook 1st Field Conf., Geology of parts of Paradox, Black Mesa, and San Juan basins, p. 89-107.

Stratigraphy of Cretaceous formations of San Juan basin, including Grants uranium region. Describes general lithology, thickness, extent of divisions, contacts, and age of individual formations, and considers sedimentary history during the Cretaceous.

Illustrations: small-scale isopach maps; nomenclature charts; electric log correlations; schematic diagram showing variable rates of Cliff House transgression, depositional environments of Mesaverde Formation, and directions of transgression and regression.

28 Breger, I. A., and Deul, Maurice, 1959, Association of uranium with carbonaceous materials, with reference to Temple Mountain region: *in* U.S. Geol. Survey Prof. Paper 320, Geochemistry and mineralogy of the Colorado Plateau uranium ores, p. 139-149.

Studies and identifies essential organic material associated with uranium in ores of the Colorado Plateau. Dakota mineralization of the Grants uranium region is mentioned. Subjects include (with presentation of experimental and analytical data) crude oils and oils as transporting agents for uranium; carbonaceous sandstone and origin of carbonaceous material in sandstone ores; carbonaceous pellets and origin of same carbonaceous shale and significance of uranium-organic association in carbonaceous shale; coalified wood and the role of coalified wood in uranium fixation.

Illustrations: thermograms; graphs of infrared absorption analyses; tables of various analytical data.

29 Brown, W. T., Jr., and Kudo, A. M., 1969, Inclusions of ultramafic and sedimentary rocks in volcanic necks, Sandoval and Valencia Counties (abs.): Geol. Soc. America Abs. with Programs for 1969, pt. 5, p. 10.

Describes igneous and sedimentary xenoliths in volcanic necks around Grants uranium region and gives particulars of composition of the necks.

30 Bryan, Kirk, and McCann, F. T., 1943, Sand dunes and alluvium near Grants, New Mexico: Am. Antiquity, v. 8, p. 281-295.

Stratigraphic study of geologically young deposits, especially sand dunes, of the Grants area (central part of Grants uranium region). Purpose of investigations is the development of a geologic yardstick for utilization in dating archaeological finds. Subjects include distribution of alluvium and dunes; relations of deposits; dating of deposits (artifacts of known pottery-culture ages and fossils are used as standards).

Illustrations: tables and figures.

31 Bucher, W. H., 1953, Fracture studies in the Zuni and Lucero uplifts, New Mexico: *in* U.S. Atomic Energy Comm. RME-3042, Annual reports for June 15, 1952, to April 1, 1953, pt. 1, 12 p.

Reports of progress in structural studies of areas bordering Grants uranium region on the south; considers relations determined in investigations. For Zuni uplift, chief topics are origin of uplift, stress orientation, vertical or horizontal, as suggested by joint patterns, the shape of the uplift, and nature of bounding structures; genesis of uranium ores on flanks of the uplift, as suggested by relations between ore distribution and joint patterns and by occurrences of fluorite. For Lucero uplift, chief topics are origin of the uplift, as suggested by general framework of Colorado Plateau structure and fracture patterns; nature of Comanche Thrust; and the possible connection of local magmatic activity with the origin of uranium ores of the area.

32 Burton, G. C., Jr., 1955, Sedimentation and stratigraphy of the Dakota Formation in the San Juan basin: *in* Four Corners Geol. Soc. Guidebook 1st Field Conf., Geology of parts of Paradox, Black Mesa and San Juan basins, p. 78-88.

Dakota Formation of San Juan basin, including Grants uranium region. Treatment emphasizes petrography, mineral composition, and texture of sandstones. Stratigraphy, especially extent of units, and depositional history and source of sediments are also considered.

Illustrations: various small-scale geologic maps, including structure-contour map of San Juan basin; electric log correlations; fence diagram illustrating extent of divisions of Dakota Formation; triangular diagrams illustrating classification of sandstones; photomicrographs.

33 Butler, A. P., Jr., and Schnabel, R. W., 1956, Distribution and general features of uranium occurrence in the United States: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 27-40.

Distribution and geology of occurrence of uranium ore in the United States. Igneous, vein, terrestrial sedimentary, marine sedimentary, asphaltic, and ground and surface water-type occurrences are explained. Stratigraphic features of deposits in Todilto Limestone of Grants uranium region are included.

34 Cadigan, R. A., 1959, Characteristics of the host rock: *in* U.S. Geol. Survey Prof. Paper 320, Geochemistry, and mineralogy of the Colorado Plateau uranium ores, p. 13-24.

Petrographic study of uranium producing formations–Chinle, Entrada, Todilto, and Morrison–of the Colorado Plateau. Information pertains in a nonspecific way to localities of Grants uranium region. Subjects include stratigraphic relations of chief divisions; textural

types and their arrangement; structural features of erosion and deposition; rock composition and classification.

Illustrations: map showing regional occurrence of chief uranium deposits.

35 Cadigan, R. A., 1967, Petrology of the Morrison Formation in the Colorado Plateau region: U.S. Geol. Survey Prof. Paper 556, 113 p.

Petrologic study of Morrison Formation on the Colorado Plateau, including Grants uranium region. The report presents information in two parts, that which pertains to the lower Morrison (Salt Wash and Recapture members) and that which pertains to the upper Morrison (Westwater Canyon and Brushy Basin members). Statistical treatment of variations in composition and texture. Described subjects include Morrison stratigraphy; modifications in lithology brought about during lithification and diagenesis of Morrison sediments; sediments of the lower Morrison and upper Morrison related to stratigraphic character, composition of sandstones, composition of fine-textured rocks, classification of rocks, parameters of texture, and the regional variations in composition, texture, source, and origin of sediments. Author considers petrologic contrasts and similarities of members; location of sources of sediment; provenance of sediments; tectonic and volcanic activity; directions of sediment transport; and depositional environments.

Illustrations: small-scale geologic maps; photographs; photomicrographs; maps of variations in Morrison sediment; maps of directional movements of sediment; tables of data.

36 Callaghan, Eugene, 1951, Tertiary and later igneous rocks of the San Juan basin: *in* New Mexico Geol. Soc. Guidebook 2nd Field Conf., South and west sides of the San Juan basin, New Mexico and Arizona, p. 119-123.

Review of distribution and nature of young igneous rocks of San Juan basin, including Grants uranium region. Description of Mt. Taylor volcanic field and the younger, post-Tertiary flows of the Grants area.

37 Cannon, H. L., 1960, The development of botanical methods of prospecting for uranium on the Colorado Plateau: U.S. Geol. Survey Bull. 1085-A, p. 1-50.

Summarizes investigations of relation of distribution of plants to ground mineralized by uranium on Colorado Plateau, including Grants uranium region and studies of botanical methods of uranium prospecting. Subjects include geology and uranium deposits of Colorado Plateau with review of chief features; geography and ecology of the Plateau (geographic setting and general distribution of plants), mountain forest climaxes and northern desert shrub vegetation; relation of plant growth to chemistry of uranium deposits; prospecting by means of indicator plants; prospecting by means of plant analysis; results of botanical prospecting on Colorado Plateau (success of application of botanical methods in uranium exploration).

Illustrations: small-scale geologic map in color (topographic base); similar map of distribution of principal types of vegetation; photographs; tables of information and analyses.

38 Chew, R. T., 3d, 1956, Uranium and vanadium deposits of the Colorado Plateau that produced more than 1,000 tons of ore through June 30, 1955: U.S. Geol. Survey Mineral Inv. Field Studies Map, MF-54.

Small scale (1/750,000), uncolored map of the Colorado Plateau, including Grants uranium region, showing location of uranium and vanadium deposits of the region.

Illustrations: table lists names of deposits; map base is a net of degrees of latitude and longitude and of lines of township and range.

39 Clark, D. S., and Havenstrite, S. R., 1963, Geology and ore deposits of the Cliffside mine, Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 108-116.

Geology and uranium deposits of Cliffside mine, Ambrosia Lake district, central part of Grants uranium region. Deposits are in Westwater Canyon Member of Morrison Formation and are part of Ambrosia Lake trend. Deposits of the mine are said to be mostly of the redistributed type. Subjects include: local Morrison stratigraphy (divisions, thicknesses, contacts, and lithology); local structure (features associated with deformation along San Mateo fault, sandstone pipes, and joint sets); form, dimensions, and orientation of ore-bodies; stratigraphic distribution (position in Westwater) of deposits; types of carbonaceous material and distribution of mineralization with respect to carbonaceous material; mineral assemblages, including ore, selenium occurrences, and black uranium-deficient sandstone (molybdenum-rich); ore controls, including channels, joints, and pre-Dakota faults; classes of redistributed unoxidized postfault ore, characteristics of outward appearance, carbon content,

vanadium content, and distribution of the two types (carbon-poor type occurs commonly near or above the water table; carbon-rich type is generally redistributed along northeast-striking fracture zones). Also considered are coloration of sediments and the presence of original red mudstone and sandstone; leaching and removal of prefault deposits along the San Mateo fault; origin of redistributed, unoxidized, postfault ores (source of uranium, and possible comparative ages of redistribution).

Illustrations: large-scale geologic map of the mine area; large-scale geologic sections; photograph.

40 Clary, T. A., and others, 1963, Geologic setting of an anomalous ore deposit in the Section 30 mine, Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 72-79.

Geology and uranium deposits of Section 30 mine, Ambrosia Lake district, central part of Grants uranium region. Deposits are in Westwater Canyon Member of Morrison Formation and are part of Ambrosia Lake trend. Deposits are primary, trend-type. Described subjects include geologic setting, local stratigraphy of Westwater, component ore trends of Ambrosia Lake trend, and directional relation of ore trends to sedimentary trend; stratigraphic distribution of mine deposits, their position in Westwater; form, dimensions, and orientation of ore bodies; distribution of deposits with respect to sedimentary features—current lineations, and erosional features (holes in the K-shale are formed in a key shale bed that separates principal ore-bearing sandstones of the Westwater); carbonaceous material and distribution of ore with respect to carbonaceous material; ore and accessory mineral assemblages; distribution of ore with respect to structural features; and the directional relation of trends of sedimentation to trends of faults. Topics include chief control of ore deposition, organic matter; through the connection of organic matter as the chief control, genesis of mine deposits (origin of the organic matter, and influence of sedimentary and structural history on its genesis and distribution).

Illustrations: small-scale map of ore trends of the area; large-scale geologic maps of ore bodies; correlation of an electric log with local stratigraphy.

41 Coleman, H. C., 1959, Origin of uranium ores in the Todilto Limestone, near Grants, New Mexico (abs.): *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 159.

Describes mineral assemblage of Todilto deposits of the central part of Grants uranium region and genesis of deposits.

42 Coleman, R. G., and Delevaux, Maryse, 1957, Occurrence of selenium in sulfides from some sedimentary rocks of the western United States: Econ. Geology, v. 52, p. 499-527.

Nature and amount of selenium within uranium deposits of the western United States, especially Colorado Plateau, and of the distribution of the selenium with respect to the ore bodies and their host stratigraphic units. Localities of analyzed samples include deposits of Grants uranium region. Study of the selenium is approached through that of the sulfide minerals, as the best possible means of detecting selenium present in the ores. The studies are within the context of investigations of processes that have produced the uranium deposits. Subjects are form and occurrence of the sulfides; distribution of selenium in the sulfides; sulfides from Morrison Formation, Entrada Sandstone, and Catskill Formation; sulfides from the Chinle Formation; sulfides from rocks of Cretaceous age; sulfides from hydrothermal and igneous rocks; mechanism of substitution, selenium for sulfur; consideration of source of selenium in rocks of Mesozoic and Tertiary age of the Colorado Plateau and Wyoming.

Illustrations: sketch of coalified log showing typical sulfide concentration; sketch of roll ore body (uranium-vanadium) and associated sulfides; sketch of sulfide band and its relation to a vanadium deposit; photomicrographs of polished sections; tables of analyses; figure showing stability field of selenium.

43 Cooley, M. E., 1959, Triassic stratigraphy in the state line region of west-central Arizona: *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 66-73.

Stratigraphy of Triassic formations (Moenkopi, Chinle, Wingate) in area including westernmost part of Grants uranium region and bordering areas to west and south. Includes divisions, thickness, contacts, distribution and facies, and lithology of formations, and also the unconformities at the base of the Triassic and at the base of Chinle. Correlation of divisions of Chinle from Zuni Mountains into central New Mexico is considered.

Illustrations: correlation chart; isometric fence diagram; figures illustrating distribution of Moenkopi Formation and Owl Rock Member of Chinle; figures showing main distributary channels and direction of transportation of sediments of Sonsela Bed (sandstone) and Correo Member (sandstone) of Chinle Formation.

44 Corbett, R. G., 1963, Uranium and vanadium minerals occurring in Section 22 mine, Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 80-81.

Occurrence and identity of ore minerals at Section 22 mine, Ambrosia Lake district, central part of Grants uranium region. Deposits are in Westwater Canyon Member of Morrison Formation and are part of Ambrosia Lake trend. Deposits of the mine are of two types, trend and stack. Ore minerals are of various valence classes and characteristics of distribution of these minerals are considered. It is inferred that primary ore deposits were of low valence and that alteration by oxidizing processes has imposed the intermediate and high-valent suites of minerals upon the low-valent association. Subjects include habit of textural and structural occurrence, and valence class of individual minerals; ore mineral assemblages of the two classes of deposits, trend and stack; zonal distribution of certain minerals.

Illustrations: table giving characteristics of occurrence of minerals and their valency.

45 Craig, L. C., and others, 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region—a preliminary report: U.S. Geol. Survey Bull. 1009-E, p. 125-168.

Stratigraphic study of Morrison Formation of Colorado Plateau, including Grants uranium region. Described subjects include pre-Morrison formations—regional stratigraphy of Glen Canyon and San Rafael groups (a sketch); lower part of Morrison Formation (Salt Wash and Recapture members)—regional stratigraphy, lithofacies, sedimentary structures, and sedimentary petrography; upper part of Morrison Formation (Westwater Canyon and Brushy Basin members)—regional stratigraphy; undifferentiated Morrison of Colorado—regional stratigraphy; post-Morrison formations (the Lower and Upper Cretaceous formations through the Mancos Shale)—general stratigraphy (a sketch); and relations of uranium deposits to Morrison stratigraphy—to thickness and lithologic class, and to texture and sedimentary structures. Considered is genesis of formations, divisions of Morrison Formation especially, depositional environments (including climate), direction of sediment transport, source of sediment (including location and provenance), and influences of tectonism and volcanism during sedimentation; genesis of uranium deposits, influence of relative permeability on migration of ore bearing solutions, and the source of the uranium.

Illustrations: fence diagram; isopach maps; combination isopach and facies maps; isolith maps; isopleth map; map of resultant dip directions of cross-laminae; location map of major carnotite deposits in Salt Wash Member and of the areas of favorable environment of ore deposition, as delimited by lithofacies criteria.

46 Cronk, R. J., 1963, Geology of the Dysart No. 1 mine, Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 60-65.

Geology and uranium deposits of Dysart No. 1 mine, Ambrosia Lake district, central part of Grants uranium region. Deposits are in Westwater Canyon Member of Morrison Formation and are part of Ambrosia Lake trend. Subjects include form, dimensions, and orientation of ore bodies; stratigraphic distribution of mineralization, position of ore bodies in Westwater Canyon Member; distribution of mineralization with respect to sedimentary features such as bedding, disconformities, argillaceous bands and galls, and structures indicating direction of sediment transport; distribution of mineralization with respect to structural features; the ore, its conspicuous aspects and mineral associates.

Illustrations: large-scale plan map of the mine; large-scale plan maps of ore bodies; large-scale geologic sections of the mine area.

47 Dane, C. H., 1959, Historical background of the type locality of the Tres Hermanos Sandstone Member of the Mancos Shale: *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 85-91.

Origin and usage of Tres Hermanos and the extent of the unit (part of lower Mancos) around Grants uranium region especially in districts bordering the central and eastern part of the region on the south. Also described is the basis for determining the age of Dakota Sandstone in the area just south of the central part of the region.

Illustrations: index map; graphic sections of Mancos Shale and lower part of Mesaverde Group; reproductions of Gilbert's stratigraphic sections and geologic sketches.

48 Dane, C. H., 1960, the boundary between rocks of Carlile and Niobrara age in San Juan basin, New Mexico and Colorado: *in* Am. Jour. Sci., v. 258-A, Bradley volume, p. 46-56.

Stratigraphic study of Cretaceous rocks of Dakota Sandstone-Satan Tongue (Mancos Shale), inclusive, and equivalents in San Juan basin. Subjects are the Dakota sandstone, Tres Hermanos Sandstone Member of Mancos Shale, Graneros Shale, and Greenhorn Limestone; beds of Carlile age in the southern part of San Juan basin; and unconformity at base of beds of Niobrara age in the northern part of San Juan basin. Described are distribution of divisions; distribution of carbonaceous rocks in Dakota Sandstone; depositional environments. Also source of sediment of Dakota Sandstone and of overlying divisions of Mancos Shale; age of divisions; especially an unconformity in the middle part of the section in the northern part of San Juan basin, evidence of the unconformity and significance of the unconformity.

Illustrations: diagrammatic sections, taken NNE-SSW across San Juan basin, of stratigraphic relations.

49 Dane, C. H., and Bachman, G. O., 1957a, The Dakota Sandstone and Mancos Shale in the Gallup area: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 95-98.

Stratigraphic study of Dakota Sandstone and Mancos Shale in Gallup area, westernmost part of Grants uranium region. Subjects include stratigraphy (lithology and thickness, depositional environments, correlation and age) of the local section of Dakota Sandstone and Early and Late Cretaceous paleogeography; and stratigraphy of the local section of Mancos Shale (lithology and thickness of divisions, contained fossils, and correlation and age of local divisions of the formation).

Illustrations: photographs; measured stratigraphic sections.

50 Dane, C. H., and Bachman, G. O., 1957b, Preliminary geologic map of the northwestern part of New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map, I-224.

Small-scale (1/380,000) geologic map of northwestern New Mexico. Grants uranium region is somewhat south of the middle of the map. As a coordinate for location, Socorro is near the middle of the south boundary of the southeastern quarter of the map.

51 Dane, C. H., and others, 1957, The Gallup Sandstone, its age and stratigraphic relationships south and east of the type locality: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 99-113.

Describes stratigraphy of Gallup Sandstone, the basal formation of the Mesaverde Group (Upper Cretaceous) around Grants uranium region.

Illustrations: photographs; small-scale maps; diagrammatic sections of stratigraphic relations; correlations of sections.

52 Dinwiddie, G. A., 1963, Ground water in the vicinity of the Jack-pile and Paguate mines: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 217-218.

Ground-water potential of formations of Laguna district in the eastern part of Grants uranium region. Subjects include local stratigraphy of the Bluff Sandstone-Mancos Shale section of Jurassic to Cretaceous age, and the overlying Quaternary alluvium; and ground-water characteristics (yield, and quality of water including quantity of dissolved solids for some wells) of various stratigraphic divisions.

53 Dodd, P. H., 1956, Examples of uranium deposits in the Upper Jurassic Morrison Formation of the Colorado Plateau: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 243-262.

Reviews geology of several Morrison deposits of the Plateau region: Poison Canyon mine, New Mexico; 4B mine, northeast Arizona; Basin No. 1 mine, southeast Utah; and Wedding Bell group, southwest Colorado. Poison Canyon mine is in central part of Grants uranium region, a trend group of Ambrosia Lake district. Subjects include local stratigraphy; local

structural geology; distribution of ore with respect to stratigraphic and structural features; ore mineral assemblage; and ore guides and controls. Treatment of Poison Canyon mine follows Konigsmark, 1955.

Illustrations: small-scale maps including combined isopach and facies map, maps showing distribution of deposits with respect to stratigraphic and to structural features; large-scale geologic maps and sections of individual mine areas.

54 Dooley, J. R., Jr. and others, 1966, Uranium-234 fractionation in the sandstone-type uranium deposits of the Ambrosia Lake district, New Mexico: Econ. Geology, v. 61, p. 1362-1382.

Morrison uranium deposits of the Ambrosia Lake district, central part of Grants uranium region. Undertaken to investigate in greater detail U^{234} fractionation through an ore zone and especially at the boundary zones of mineralization and to compare the fractionation in different types of ore from within the same mining district. Subjects are geologic setting; uranium deposits, including summary of geology of Morrison deposits of Ambrosia Lake district and locality description of samples; procedure and results; mechanism of U^{234} fractionation; uranium fractionation and migration; and summary and conclusions.

Illustrations: tables of analyses; graphs of U^{234} fractionation and uranium content in suites of samples taken across ore layers; graphs of radioisotopic decay relations in the suites of samples.

55 Duschatko, R. W., 1953, Fracture studies in the Lucero uplift, New Mexico: U.S. Atomic Energy Comm. RME-3072, 49 p.

Studies structural geology around Lucero uplift in southern part of the eastern end of Grants uranium region and bordering areas to the south. Considers relative importance of horizontal and vertical movements in the development of structure. Subjects include structural geology of Carrizo Arroyo area including overall structure, high-angle faulting, gypsum flowage and associated sliding and brecciation of adjacent beds, low-angle faulting, rootless masses and slump structures; structural geology of Gray Mesa area; including overall fracturing, joints, and areal fracture pattern.

Illustrations: small and large-scale geologic maps (large-scale maps are 1/7920; bases are topographic); large-scale geologic sections; diagrammatic sections; block diagram; joint diagrams (orientation); table of stratigraphic descriptions.

56 Ellsworth, P. C., and Mirsky, Arthur, 1952, Preliminary report on relation of structure to uranium mineralization in the Todilto Limestone, Grants district, New Mexico: U.S. Atomic Energy Comm. RME-4020, 15 p.

Relation of mineralization and structure in outcropping Todilto Limestone of Ambrosia Lake area, central part of Grants uranium region. Subjects include folds, their dimensions, shapes, and structural relation of associated joints and faults; and distribution of mineralization. Also control of localization of mineralization by structure; genetic relation of joints and folds; origin of structure; spacing of drill-holes necessary to determine structure.

Illustrations: small-scale, structure-contour maps of the base of Todilto with areas of known mineralization additionally delimited.

57 Erickson, R. L., and others, 1954, Association of uranium and other metals with crude oil, asphalt, and petroliferous rock: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 2200-2218.

Studies uranium in crude oil, natural asphalt, and other petroliferous materials as part of broader investigations of the widespread association of uranium and organic material in sedimentary rocks. Study investigates the idea that uraniferous asphaltic materials might aid in understanding the origin and distribution of certain uranium deposits. It summarizes work carried out during 1952 on the uranium and minor-element content of a few samples of crude oil, natural asphalt, and petroliferous rock and points out possible relation of the minor-element content to the formation of some types of uranium deposits. Work included study of uraniferous asphaltite from Poison Canyon Mine–a Morrison deposit of Poison Canyon trend, Ambrosia Lake district, central part of Grants uranium region. At the time of investigations, the asphaltite was assumed to be a petroleum derivative. Subjects are crude oil; solid asphalt; petroliferous rock; nature and origin of metal compounds in petroleum.

Illustrations: tables of analyses; graph comparing distribution of metals in oil extracted from petroliferous rock and distribution in the extracted rock; table comparing metal content of oil extracted from petroliferous rock and content of the extracted rock.

58 Erskin, W. S., 1959, "Micrometeorites" of the Todilto gypsum–a preliminary

investigation (abs.): *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 161.

Describes meteoritic dust in Todilto Formation.

59 Finch, W. I., 1964, Epigenetic uranium deposits in sandstone: *in* U.S. Geol. Survey Prof. Paper 501-D, Short papers, p. 76-78.

Summarizes consequential features of the geology of certain epigenetic uranium deposits in the conterminous United States. Treatment includes deposits of Grants uranium region. Author's abstract: "Nearly all of the approximately 4,600 sandstone uranium deposits in the United States are in continental sediments that accumulated in shallow, poorly drained foreland or post orogenic basins. Data from these deposits suggest that the uranium was precipitated from alkaline connate-water solutions during and after diagenesis under reducing conditions at normal rock temperatures and pressures."

Illustrations: map of the conterminous United States, showing distribution of epigenetic uranium deposits in sandstone and related foreland areas.

60 Finch, W. I., 1967, Geology of epigenetic uranium deposits in sandstone in the United States: U.S. Geol. Survey Prof. Paper 538, 121 p.

Reviews geologic studies and explorations of uranium deposits in sandstone in the United States from 1943 to 1959 (citations from pertinent literature date into 1967). Deposits of Grants uranium region are mentioned specifically. Subjects include geochemical distribution of uranium; geographic, stratigraphic distribution of deposits; lithology of host rocks; deposition and history of the host rocks, tectonic setting, and geologic history of uranium-bearing regions; character of deposits such as chemical composition, mineral composition, ore textures, shape and size of deposits, alteration of host rocks; localization of deposits, relation to sedimentary features, tectonic features, and igneous and metamorphic rocks. Also determinations of age of deposits; genesis of deposits; areas favorable for further exploration.

Illustrations: small-scale geologic maps and sections; graphs illustrating distribution of deposits with respect to age of host rocks, range in grades and ratios of U_3O_8 and V_2O_5 for ores from selected stratigraphic units and areas, ranges in sulfur isotope ratios for certain deposits, distribution of deposits by size in sandstones of Triassic age in the Colorado Plateau, distribution of total ore removed with respect to size of deposit in sandstone of Triassic age in the Colorado Plateau.

Tables: average uranium content of certain rocks, major characteristics of individual deposits, stratigraphic units that contain deposits and their geologic characteristics, dominantly intrinsic elements in sandstone and in ore in the Colorado Plateau, geometric mean content of dominantly extrinsic elements in ore and barren sandstone from parts of formations of the Colorado Plateau, uranium minerals of deposits, apparent isotopic ages of ore (samples from the Colorado Plateau) and age limits of the geologic periods of the host formations, the historical development of hypotheses of origin of deposits, and continental sandstone formations in which uranium deposits are unknown.

61 Finch, W. I., and others, 1959, Epigenetic uranium deposits in the United States: U.S. Geol. Survey Misc. Geol. Inv. Map, I-299.

Three map sheets. Sheet 1: *Distribution of epigenetic uranium deposits and continental sedimentary rocks* is a small-scale (1/5,000,000) map of the conterminous United States showing distribution of sedimentary rocks of Precambrian, Paleozoic, Mesozoic, and Cenozoic age and location of vein-type deposits and sorts of concordant-type deposits classified according to type of host rock. Sheet 2: *Distribution of epigenetic uranium deposits and igneous and metamorphic rocks of pre-Late Cretaceous age* shows distribution of Precambrian igneous and metamorphic rocks (undifferentiated), Paleozoic extrusive rocks, Paleozoic intrusive rocks, Mesozoic extrusive rocks (exclusive of those of Late Cretaceous age), and Mesozoic intrusive rocks (exclusive of those of Late Cretaceous age) and location of deposits of vein-type and concordant-type. The two types of deposit are also differentiated by symbol according to age of host rock. Sheet 3: *Distribution of epigenetic uranium deposits and igneous rocks of Late Cretaceous and Cenozoic age* shows distribution of extrusive rocks of Late Cretaceous and Cenozoic age and location of deposits of vein and concordant types.

62 Fischer, R. P., 1956, Uranium-vanadium-copper deposits on the Colorado Plateau: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 143-154.

Reviews distribution and geology of occurrence of uranium deposits on the Plateau. Subjects include gross aspects of distribution of deposits, stratigraphic and lithologic; metal components of ore assemblage; interpretation of distribution of classes of deposits; mineral-

ogy of ore minerals and features of mineral occurrence; gross aspects of ore bodies, such as size, shapes, relations to stratigraphic and to structural features; mineral belts (groups of deposits distributed in belts), aspects of occurrence; localization of ores, stratigraphic and structural controls; age of deposits; concepts or origin. Includes discussion of distribution and mineralogy, and shape of deposits of Grants uranium region, especially Todilto deposits.

Illustrations: small-scale maps of distribution of classes of deposits.

63 Fisher, R. P., 1968, The uranium and vanadium deposits of the Colorado Plateau region: *in* New York, Am. Inst. Mining Metall. Petroleum Engineers, Inc., v. 1, Ore deposits of the United States, 1933-1967 (Graton-Sales volume), p. 735-746.

Summarizes geology of uranium on the Colorado Plateau. Brief mention of features of Grants uranium region. Paper comprises series of summaries each of which describes geology of a separate uranium province of the Plateau. Subjects include production data and history of mining; geologic history, a sketch; structure and igneous activity, general review; stratigraphy of uranium-bearing rocks, especially Chinle and Morrison Formations; ore deposits, their mineralogy and elemental composition, ore bodies (form, size, grade, and localization), rock alteration, age of mineralization, and genesis.

Illustrations: map showing major structural features, principal igneous features, and chief uranium producing areas of the Plateau; table of production data; stratigraphic chart.

64 Fischer, R. P., 1970, Similarities, differences, and some genetic problems of the Wyoming and Colorado Plateau types of uranium deposits in sandstone: Econ. Geology, v. 65, p. 778-784.

Characteristics of the Wyoming roll and Colorado Plateau peneconcordant types of uranium deposits. Investigation focuses attention on genetic problems. Specifically mentioned are Morrison deposits of Grants uranium region. Subjects include Wyoming roll-type deposits, geographic occurrence, gross aspects of stratigraphy of region, host rock, form and dimensions and boundaries of ore bodies, distribution of ore bodies, distribution of ore with respect to particulars of stratigraphy of host rock, mineral and element assemblages of ore bodies, distribution of roll ore bodies with respect to an interface between altered and unaltered sandstone, distinctions of altered and unaltered sandstone, and aspects of genesis of deposits; Colorado Plateau peneconcordant-type deposits, stratigraphic distribution of deposits, host rock, general tectonic history of region, form and dimensions and distribution of deposits, with respect to stratigraphy of host rock, distribution of ore, ore boundaries, distribution of grade ore in deposits, mineral and metal assemblages of deposits, deposits with respect to altered rock, lithology of altered rock and results of alteration, and aspects of genesis of deposits. Discussion includes Eh of ore-bearing solutions of both the Wyoming and Plateau deposits; shape and localization of ore bodies, explanations for the shape and localization of the Wyoming and Plateau deposits; source of uranium with various possibilities in the Wyoming and Colorado Plateau deposits and in deposits of the Texas coastal region and those in the Black Hills of South Dakota and Wyoming.

Illustrations: chart outlining similarities and dissimilarities of the Wyoming roll and Colorado Plateau peneconcordant types of uranium deposits.

65 Fischer, R. P., and Stewart, J. H., 1960, Distribution and lithologic characteristics of sandstone beds that contain deposits of copper, vanadium, and uranium: *in* U.S. Geol. Survey Prof. Paper 400-B, Short papers, p. 42-44.

Summarizes principal features of distribution of sandstone-type deposits of copper, uranium, and vanadium in the United States, with mention of Morrison deposits of Grants uranium region. Subjects include form of deposits; geographic areas of occurrence; age, chief lithology, and genetic type of the various host sandstones; type of strata associated with host rock if significant; texture of ores; and mineral assemblages. Also source of the metals.

Illustrations: table of chief features of distribution and characteristics of the sandstone hosts of deposits of copper, vanadium, and uranium.

66 Fischer, R. P., and Stewart, J. H., 1961, Copper, vanadium, and uranium deposits in sandstone—their distribution and geochemical cycles: Econ. Geology, v. 56, p. 509-520.

Distribution of copper, vanadium, and uranium relative to respective geochemical cycles; includes deposits of Grants uranium region. Authors observe, ". . . recent studies suggest a selective relationship between the metal content of the deposits and the lithologic and genetic characteristics of the host rocks." Includes habits of the deposits; characteristics of the host sandstones and distribution of metals; geochemical cycles of the metals. Subjects under habits

of the deposits are ore mineral assemblage of unoxidized deposits; manner of textural occurrence in sandstone hosts; form of deposits; influence of sedimentary structures, tectonic structures, and proximity of igneous intrusives and hydrothermal veins on characteristics of deposits. Subjects under characteristics of the host sandstones are characteristics of host sandstones, abundance of contained organic matter, abundance of contained or associated altered volcanic debris, and range in composition of principal ore-bearing sandstones; distribution of metals with respect to composition, texture, and provenance of host sandstones; characteristics of particular host formations in connection with distribution of metals. Subjects under geochemical cycles of the metals follow. For copper: distribution in igneous rocks, availability for hydrothermal transport, availability for dispersion through sedimentary processes, distribution in surface water and in ground water, distribution in sedimentary rocks, and sedimentary environment of concentration. For vanadium: distribution in igneous rocks and in minerals in igneous rocks and manner of occurrence in the minerals, availability of vanadium for hydrothermal transport, manner of dispersion in sedimentary processes, distribution in sedimentary rocks, distribution in suspended material and in solution in waters from Black Sea basin rivers, influence of climate on the degree of oxidation of source rocks and consequent manner of sedimentary dispersion, and sedimentary environment of concentration. For uranium: distribution and manner of occurrence in igneous rocks, occurrence in hydrothermal veins, availability for dispersion through sedimentary processes, distribution in sedimentary rocks, and sedimentary environments of accumulation and concentration.

Illustrations: chart showing distribution and characteristics of host sandstones; diagrams of composition of the sandstones; map showing distribution and type of ore deposits in Shinarump Member and in Agua Zarca Sandstone Member of Chinle Formation; table of average content of copper, vanadium, and uranium in common rock types.

67 Fitch, D. C., 1971, Exploration geology methods in the Grants Mineral Belt: *in* New Mexico Bureau Mines Mineral Resources Circ. 118, Selected papers from 1970 uranium symposium at Socorro, New Mexico, p. 13-28.

Reviews geology of Morrison uranium deposits of Grants uranium region and describes exploration techniques and methods practiced commonly in the region. Subjects include Morrison stratigraphy; characteristics of distribution of Morrison deposits; ore guides; theories of genesis of deposits; plan of exploration programs, including land acquisition, drilling, logging, and costs.

Illustrations: numerous reproductions of geologic maps and sections; photographs; portrayals of various types of logs, such as drill, geophysical, drift; representation of typical exploration costs.

68 Fitzsimmons, J. P., 1959, The structure and geomorphology of west central New Mexico: *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 112-116.

Sketches structural geology and geomorphology of west central New Mexico including Grants uranium region.

Illustrations: sketch map of tectonic elements of the region.

69 Fitzsimmons, J. P., 1967, Precambrian rocks of the Zuni Mountains: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 119-121.

Studies westernmost Precambrian rocks of Zuni Mountains, bordering western part of Grants uranium region on the south. Texture, mineral composition, and structure of the rocks are described. Several observations are the contrast between class of rocks exposed in the western part of the mountains and the eastern; outward similarity in resistance to erosion of Precambrian rocks and overlying rocks in connection with structural considerations; comparatively youthful appearance of structural features.

Illustrations: index map.

70 Foster, R. W., 1957, Stratigraphy of west-central New Mexico: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 62-72.

Summarizes geology of west-central New Mexico. Region includes Grants uranium region and areas to the south, as well as northern parts of Catron and Socorro Counties. Subjects are Precambrian, pre-Pennsylvanian Paleozoic, Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, Cenozoic rocks, and late Tertiary to Recent basalt flows.

Illustrations: small-scale geologic maps; table of information related to important oil tests of the region.

71 Freeman, V. L., and Hilpert, L. S., 1956, Stratigraphy of the Morrison

Formation in part of northwestern New Mexico: U.S. Geol. Survey Bull. 1030-J, p. 309-334.

Stratigraphic study of Morrison Formation of the central and eastern parts of Grants uranium region and areas bordering the eastern part of the region on the north. Investigations are to clarify stratigraphic relations in the Laguna area, in the eastern part of the region where stratigraphic nomenclature was inconsistent with that elsewhere in the region. Conclusion is that the Jackpile Sandstone of Laguna area is a division of Brushy Basin Member of Morrison Formation rather than part of Westwater Canyon Member of Morrison Formation. Subjects are previous stratigraphic work; general stratigraphy of Morrison Formation in northwestern New Mexico, including Recapture Member, Westwater Canyon Member, and Brushy Basin Member; stratigraphy of Morrison Formation near Laguna.

Illustrations: charts showing development of stratigraphic nomenclature; correlation of stratigraphic sections; tables of measured sections.

72 Frondell, Clifford, 1958, Systematic mineralogy of uranium and thorium: U.S. Geol. Survey Bull. 1064, 400 p.

Systematic and comprehensive description of uranium and thorium minerals, together with a few rare-earth minerals containing uranium and thorium as nonessential constituents. For treatment of minerals, author uses a chemical classification; groups: oxides, carbonates, sulfates, molybdates, phosphates and arsenates, vanadates, silicates, and multiple oxides (niobate-tantalate-titanates). Each species is described according to its synonymy, composition, crystallography, physical properties, optical properties, synthesis, identification, natural formation, and occurrence.

Illustrations: figures and tables.

73 Gabelman, J. W., 1956a, Structural control of uranium deposits in the Zuni-Mt. Taylor region, N.W. New Mexico (abs.): Econ. Geology, v. 51, p. 114.

Describes distribution of uranium deposits of Grants uranium region with respect to structure. Author remarks: "Belts of uranium mineralization extend incompletely around both major structures (Zuni uplift and McCarty syncline) with strongest mineralization in the fringe of the intersection zone. The intersection zone and each structure center are suggested as solution sources."

74 Gabelman, J. W., 1956b, Uranium deposits in paludal black shales, Dakota Sandstone, San Juan basin, New Mexico: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 303-319.

Studies uranium deposits of Dakota Sandstone of southern San Juan basin, including Grants uranium region. For each deposit, subjects include local stratigraphy; local structure; form of deposit; distribution of ore with respect to stratigraphy and structure mineral assemblage. Genesis of deposits is considered using migration of solutions, trapping mechanisms, precipitants, and age of mineralization.

Illustrations: small-scale geologic maps of the region; large-scale geologic maps and sections of mine areas; measured stratigraphic sections; photographs.

75 Gabelman, J. W., 1956c, Uranium deposits in limestone: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 387-404.

Reviews distribution of uranium in limestones, especially mineralization in Todilto Limestone of Grants uranium region. Described subjects (Todilto) include regional stratigraphy; diagenetic deformation; structural setting of mineralized areas; local structure of mineralized areas; widespread recrystallization of the upper part of the limestone; form of deposits; distribution of uranium with respect to stratigraphic and structural features; mineral assemblages. Also considered: origin of structural features peculiar to Todilto Limestone; depositional environment of Todilto; aspects of genesis of deposits, including migration of uranium-bearing solutions and controls of migration, source of uranium, and age of mineralization.

Illustrations: small-scale geologic maps of the region; large-scale geologic maps and sections of mineralized areas; photographs.

76 Gabelman, J. W., 1957, The origin of collapsed-plug pipes: Mines Mag., v. 47, no. 9, p. 67-72, 79-80.

Study of collapsed-plug pipes of the Colorado Plateau, including Grants uranium region. Subjects include geographic distribution of pipes with respect to structural features and to centers of volcanic activity; clustering of pipes; form and dimensions of pipes; margins of

pipes and marginal fractures; condition of rock in the central sedimentary plug; relative movement of sedimentary plug with respect to surrounding rock and amount of displacement; similar pipe structures of the Plateau, such as breccia collapse pipes without plugs, collapsed pyroclastic surface vents, uncollapsed pipes with no igneous material, basalt plugs, intrusive clastic plugs, piercement salt plugs, and solution sink holes. Genesis of the pipes is discussed by review of the solution cave theory, and the explosive pipe theory; description and discussion of the cryptovolcanic theory (advanced by the author).

Illustrations: photographs; sketches of section views of idealized pipe structures.

77 Gabelman, J. W., 1970, The Flat Top uranium mine, Grants, New Mexico: U.S. Atomic Energy Comm. RME-4112, 81 p.

Comprehensive study of a Todilto uranium deposit (Flat Top mine) of Ambrosia Lake area, central part of Grants uranium region. Subjects include geologic setting of the mine, regional geology, geology of Ambrosia Lake area, and geology of Poison Canyon area (a part of Ambrosia Lake area and the locality of Flat Top mine); geology of Flat Top mine. Items of regional and general geology of Ambrosia Lake area include stratigraphy of the section Wingate Sandstone-Dakota Sandstone inclusive, especially stratigraphy of Todilto Limestone; structural geology, Zuni arch, folds including those peculiar to Todilto Limestone, faults, pipes, history of deformation, and relation of structural features to Zuni arch; intrusive and volcanic rocks of area; uranium deposits, especially Todilto classes of deposits, distribution of these deposits with respect to Morrison deposits, similarities and dissimilarities of Todilto deposits and those of sandstone hosts, clustering of Todilto deposits and distribution of clusters with respect to shallow folds of the area. Poison Canyon area subjects include local stratigraphy of Todilto Limestone; local structural geology, such as Poison Canyon syncline, faults, and pipes; Todilto uranium deposits of the area, form and size of deposits, grade of mineralization, distribution of Todilto and Morrison deposits with respect to Poison Canyon syncline, and distribution of mineralization with respect to faults. Flat Top mine geology includes local stratigraphy of Todilto Limestone and adjacent beds of the underlying Entrada and overlying Summerville formations; alteration of host rocks by bleaching, recrystallization, argillization, and dolomitization; local structural geology including Todilto folds, faults (high-angle, low-angle), mineralization (characteristics of distribution of ore, ore texture and structure, mineral assemblages, and paragenesis of events and minerals). Also guides for use in exploring for Todilto ores. Subjects are stratigraphy, origin of formations, especially Todilto Limestone; alteration, origin of alteration of Todilto Limestone and adjacent strata; structural geology, genesis of structural features including relation of folds and fractures to Zuni uplift, age of deformation, and variety and orientation of deforming stresses; genesis of deposits, age of mineralization, physical and chemical controls of localization of ore, source of uranium, nature of transporting solutions, and mechanisms (possible reducing agents) of precipitation of uranium.

Illustrations: stratigraphic chart; small-scale geologic maps of general area; large-scale mine maps, structure-contour, isopach, ore grade-thickness, and wall maps; photographs, radio-authographs, photomicrographs from thin sections.

78 Gabelman, J. W., and others, 1956, Uranium—Ambrosia Lake—New Mexico's newest bonanza: Mines Mag., v. 46, no. 3, p. 58-64, 72-73; April 1956, Uranium Mag., p. 8-10, 26-31.

Description, previously given in a talk before the Colorado Mining Association Convention held February 2, 3, 4, 1956 in Denver, of the discovery and geology of occurrence of Morrison uranium ore of Ambrosia Lake district (central part of Grants uranium region). Subjects include geologic setting; history of exploration and development of concepts used in uranium exploration.

Illustrations: geologic map; graphic column; stratigraphic section.

79 Gabelman, J. W., and others, 1957, The origin of collapsed plug pipe—a discussion: Mines Mag., v. 47, no. 12, p. 31-32.

Addendum to earlier treatment of the solution cave theory of explanation of genesis of collapsed plug pipes of the Colorado Plateau (Gabelman, 1957). Considers extent of downward vertical displacement of the central plug of a pipe structure that could be expected from collapse of the plug into a cavity formed in soluble rock below, as a function of the thickness of the soluble formation. Results find solution cave theory unattractive as explanation of origin of collapsed plug pipes.

80 Gay, I. M., 1963, Uranium mining in the Grants district: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 244-246.

Describes methods used in mining uranium deposits of Grants uranium region. Subjects include: open-pit mining; underground mines above the water table (water conditions, modes

of entry, development, stoping, and ventilation); and underground mines below the water table (treatment, as above).

81 Gilkey, A. K., 1953, Fracture pattern of the Zuni uplift: U.S. Atomic Energy Comm. RME-3050, 34 p.

Studies structural geology, especially fracture patterns, of Zuni uplift. Investigation includes southern parts of the western half of Grants uranium region and bordering areas to the south. Study is to determine the chief fracture pattern of Zuni uplift and, through analysis of the pattern, origin of the uplift. Author approaches question of origin by comparing characteristics of the fracture pattern of Zuni uplift with those of fracture patterns of smaller anticlines, the origins of which are diverse but believed known. Folds utilized as standards for an origin by lateral compression are an anticline in Woods Hollow Mountains of Marathon folded belt, west Texas; part of Wills Mountain anticline in the folded Appalachians of northwestern Virginia. The fold utilized as a standard for an origin by passive doming is Maze Arch, a laccolithic dome in Henry Mountains of Utah. Subjects include general form of Zuni uplift; directional orientation of structural features with respect to trend of uplift; bounding structures of the uplift where present; fault and joint patterns of the uplift; fracture patterns of folds used as standards of comparison; origin of Zuni uplift (doming); mechanism of doming (horsting); age of fracturing; Zuni uplift in relation to regional structural trends, deep fracture zones, and adjacent uplifts; relation of fracturing to uranium deposits; possibility of extension of mineralization beyond known areas of deposits along trend of fracture zones.

Illustrations: small-scale geologic maps of area; map of structure contours of the base of Todilto Limestone; small-scale geologic maps of folds utilized as standards of comparison.

82 Goddard, E. N., 1966, Geologic map and sections of the Zuni Mountains fluorspar district, Valencia County, New Mexico: U.S. Geol. Survey Misc. Geol. Inv. Map, I-454.

Small-scale (1/31,680), colored geologic map (topographic base) of the core part of the southeastern portion of Zuni uplift, which borders the central and west-central part of Grants uranium region on the south; geologic sections; accompanying text describing geology of the area. Subjects include structural geology of the area; wall rock alteration along faults; geology of fluorspar deposits. Also form of uplift; structural features of the district (foliation, lineation, faults, effects of chief faulting, and similarities of principal faults of the district and the breccia reef faults of Front Range mineral belt of Colorado). Structural features are classified by two chief ages, Precambrian and post-Permian (possibly Tertiary). Elements of relatively older (early Tertiary, Laramide) origin and of relatively younger, unspecified age. Wall rock alteration along faults includes the alteration; distribution with respect to faults; evidence of age of alteration. Also considered is the implication of the occurrence of alteration in some areas where faults are not conspicuous. Subjects on fluorspar deposits are general distribution of deposits in area; fluorspar veins and contained minerals; distribution of deposits with respect to structure; grade of fluorspar; distribution of grade of mineralization in deposits with respect to details of structure; guides to finding ore, genesis of deposits, source of ore solutions; identity of the trunk conduits of the mineralizing solutions.

83 Gordon, E. D., 1961, Geology and ground-water resources of the Grants-Bluewater area, Valencia County, New Mexico: New Mexico State Engineer Tech. Rpt. 20, 109 p.

Ground-water resources and geology in the Grants-Bluewater area, central part of Grants uranium region. Subjects include local structural geology, stratigraphy, and geologic history; water table; ground-water recharge, movement, and discharge; ground-water development and use; fluctuations of water levels; aquifer characteristics; factors that influence quality of water; chemical character of water in the geologic formations.

Illustrations; small-scale (1/62,500) geologic map of Grants-Bluewater area; photographs; contour map of water-level; map of chief faults; stratigraphic sections; core logs; ground-water data and analyses.

84 Gott, G. B., and others, 1952, Uranium in black shales, lignites, and limestones: *in* U.S. Geol. Survey Circ. 220, Selected papers on uranium deposits in the United States, p. 31-35.

Geology of deposits in carbonaceous rocks of the United States including aspects of genesis of the deposits. Mentions mineralization in Todilto Limestone of Ambrosia Lake area, central part of Grants uranium region.

Illustrations: small-scale maps of distribution of mineralization in shales, coals, and limestones.

85 Gould, Walter, and others, 1963, Geology of the Homestake-Sapin uranium deposits, Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral

Resources Mem. 15, Geology and technology of the Grants uranium region, p. 66-71.

Geology and uranium deposits of Section 15, Section 23, and Section 25 mines, Ambrosia Lake district, central part of Grants uranium region. Deposits in Westwater Canyon Member of Morrison Formation are part of Ambrosia Lake trend and include primary (trend-type) and redistributed (stack-type) ore bodies. Subjects include structural features of the mine, especially fractures; stratigraphic distribution of ore bodies, positions of deposits in the Westwater; form, dimensions, and orientation of ore bodies; distribution of redistributed (stack) ore with respect to fractures and to coloration of sediment; the reaction zone between barren rock and ore in redistributed deposits; accessory mineral assemblage; distribution of vanadium and selenium in redistributed deposits; ore guides. Considered is genesis of the redistributed deposits: source of uranium, date and distance of migration of uranium, controls of distribution (features that may influence permeability of rock).

Illustrations: small-scale geologic map of the mine area; large-scale geologic sections.

86 Granger, H. C., 1960, Pitchblende identified in a sandstone-type uranium deposit in the central part of the Ambrosia Lake district, New Mexico: *in* U.S. Geol. Survey Prof. Paper 400-B, Short papers, p. 54-55.

Report of first identification of pitchblende from Morrison deposits of the central part of Ambrosia Lake district, Kermac Section 22 mine of Ambrosia Lake trend. District is in the middle part of Grants uranium region. Description of relations of the mineral and consideration of the source of the uranium in the mineral.

87 Granger, H. C., 1962, Clays in the Morrison Formation and their spatial relation to the uranium deposits at Ambrosia Lake, New Mexico: *in* U.S. Geol. Survey Prof. Paper 450-D, Short papers, p. 15-20.

Studies Morrison clays around Ambrosia Lake (central part of Grants uranium region). Investigations concern testing, in Ambrosia Lake ore, a prevailing hypothesis that layer-type and roll-type uranium ores in sandstone were deposited at an interface between two natural solutions of different characteristics. Included are Morrison stratigraphy; distribution of primary ores and later unoxidized ores of the Morrison at Ambrosia Lake; distribution of clay minerals, montmorillonite, kaolinite, and chlorite, in the Morrison of the area.

Illustrations: generalized geologic section; variations in concentration of elements and clay minerals across ore layers.

88 Granger, H. C., 1963a, Radium migration and its effect on the apparent age of uranium deposits at Ambrosia Lake, New Mexico: *in* U.S. Geol. Survey Prof. Paper 475-B, Short papers, p. 60-63.

Problems in determining the absolute age of original uranium mineralization in Morrison deposits of Ambrosia Lake district (located in the central part of Grants uranium region) and derivations of the apparent age of mineralization. Discussion of migration of uranium and radiogenic elements. Subjects include selection of a standard for recognizing migration of elements; current distribution of elements relative to the standard in rocks of ore bodies and their bordering areas; relative span-of-time of migration of elements and connected effects on age determination by isotopic methods; comparative importance of long-continued loss of radium or modern loss of uranium in determination of age by isotopic methods; age to be expected from isotopic determinations in different parts of the ore body; method for deriving age of original mineralization.

Illustrations: correlation of uranium and equivalent ionium in samples; figures comparing abundance of various radioisotopes with equivalent protactinium in ore and rock of differing parts of ore bodies.

89 Granger, H. C., 1963b, Mineralogy, *in* Geology and technology of the Grants uranium region: New Mexico Bureau Mines Mineral Resources Mem. 15, p. 21-37.

Description and classification of mineral assemblages of uranium deposits of Grants uranium region. Chief basis of classification of mineral assemblages is valence state of uranium, reduced (U^{+4}) or oxidized (U^{+6}), in the uranium minerals. This broadly divides most deposits into primary and secondary (weathered) mineral assemblages. Where data are available, information leads to further division: minerals in deposits of unoxidized environment in Westwater Canyon Member of Morrison Formation; minerals in deposits of oxidized environment in the Westwater. Information under deposits in the Todilto Limestone; deposits in the Westwater Canyon Member of the Morrison Formation; deposits in the Jackpile Sandstone (of economic usage) Morrison Formation.

Illustrations: listing of minerals in deposits of Westwater Canyon Member according to environment; tables of authigenic minerals from deposits of various host rocks of the region.

90 Granger, H. C., 1968, Localization and control of uranium deposits in the southern San Juan basin mineral belt, New Mexico–an hypothesis: *in* U.S. Geol. Survey Prof. Paper 600-B, p. 60-70.

Genesis of Morrison uranium deposits of Grants uranium region. Particular attention given to source of organic matter that apparently controls localization of primary mineralization to gain understanding of overall beltlike distribution of deposits. Includes review of local Morrison stratigraphy; description of post-Morrison-pre-Dakota geography; review of Dakota stratigraphy; review of major characteristics of ore deposits; review of evidence–stratigraphic, structural, and isotopic–of age of mineralization; possible sources of organic matter as a framework of geologic relations; areas favorable for further exploration.

Illustrations: small-scale geologic maps and section.

91 Granger, H. C., and Ingram, B. L., 1966, Occurrence and identification of jordisite at Ambrosia Lake, New Mexico: *in* U.S. Geol. Survey Prof. Paper 550-B, Short papers, p. 120-124.

Studies black amorphous substance closely associated with some uranium ores of Ambrosia Lake district, central part of Grants uranium region. Black matter is tentatively confirmed as jordisite. Subjects include distribution of jordisite; characteristics of jordisite separates; results of elemental analyses of samples from rock containing jordisite; mode of textural occurrence; form of jordisite bodies; characteristics of the distribution with respect to lithology, class of uranium ore body, and individual zones of uranium mineralization; distribution of molybdenum with respect to selenium. Also the identity of minerals in samples from determinations of elemental composition; identity and form of molybdenum mineral in samples.

Illustrations: table of geographic and geologic location of samples; tables of analyses.

92 Granger, H. C., and Santos, E. S., 1963, An ore-bearing cylindrical collapse structure in the Ambrosia Lake uranium district, New Mexico: *in* U.S. Geol. Survey Prof. Paper 475-C, Short papers, p. 156-161.

Studies uranium deposit in a sandstone pipe, Doris No. 1 mine of Poison Canyon trend, Ambrosia Lake district, central part of Grants uranium region. Subjects include local Morrison stratigraphy; cylindrical collapse structure, including displacement and form of bounding faults, condition of strata within structure; distribution of ore with respect to stratigraphy and structure; mineral assemblages and distribution of particular suites of minerals; distribution of organic carbon, lead, molybdenum, vanadium, and selenium with respect to uranium. Topics considered: classification of the deposit; origin of the cylindrical collapse structure; structure as a conduit for mineralizing solutions of juvenile origin.

Illustrations: small and large-scale geologic maps; large-scale geologic sections; illustration of distribution of certain elements with respect to uranium.

93 Granger, H. C., and Warren, C. G., 1969, Unstable sulfur compounds and the origin of roll-type uranium deposits: Econ. Geology, v. 64, p. 160-171.

Experimental study of origin of roll-type uranium ore deposits such as those said to occur in the Tertiary basins of Wyoming and in Jurassic rocks at Ambrosia Lake, New Mexico. Approach is through considering the genesis of the associated iron sulfides. There appears to be a lack of sufficient organic matter to support the bacterial activity necessary to produce the abundance of pyrite observed along the roll face in such deposits as those of Shirley basin, Wyoming. The paper proposes an alternative mechanism (inorganic) for the formation of pyrite in deposits. Subjects include: the hypothetical model; synthetic roll models; mineral syntheses; oxidation of pyrite; intermediate reactions; reconstitution of iron sulfides; sulfur isotopes; other supergene deposits; conclusions.

Illustrations: geologic maps and sections; sketch of laboratory equipment; graphs of equilibrium distribution of sulfur species.

94 Granger, H. C., and others, 1961, Sandstone-type uranium deposits at Ambrosia Lake, New Mexico–an interim report: Econ. Geology, v. 56, p. 1179-1210.

Studies geology of Morrison uranium deposits of Ambrosia Lake district, central part of Grants uranium region. Subjects include local stratigraphy, chiefly Morrison; local structural geology; ore deposits, their form, distribution (with respect to stratigraphic unit, structural elements, sedimentologic details, and color of sandstone), mineral assemblage, accessory-mineral assemblage, occurrence of individual minerals, distribution of elements in ores

relative to ore boundaries, and variations in distribution of uranium and daughter products in ore deposits. Also classification of deposits on structural basis (prefault and postfault); organic matter in ore by identification and source of material.

Illustrations: small-scale structure map; block diagram of typical form and distribution of ore bodies in district; large-scale geologic sections of ore bodies; graphs of element distribution and radioisotope relations in ore bodies; graph of radioisotope equilibrium (U/eU) relations.

95 Green, M. W., and Pierson, C. T., 1971, Geologic map of the Thoreau NE quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-954.

Geologic map, topographic base, of a 7½-minute quadrangle in the central part of Grants uranium region.

96 Grundy, W. D., and Meehan, R. J., 1963, Estimation of uranium ore reserves by statistical methods and a digital computer: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 234-243.

Statistical methods of estimation of ore reserves in sandstone-type uranium deposits of the western United States, using gamma-ray log data from drill holes; statistical characteristics of distribution of assay values and the mathematical model of distribution. Subjects include advantages of statistical model in ore reserve estimation; the lognormal distribution (definition); mathematical formulas; estimation of tonnages and average grades of various cut-offs and confidence limits; computer programs; example of results of utilizing statistical methods in ore reserve calculations; economic considerations.

Illustrations: histogram of assay values; graphic representation of relation of tonnage, average grade, and pounds (U_3O_8) with logarithm variance; flow diagram of computer procedure; table of analysis of ore reserves of ore block in Ambrosia Lake area.

97 Gruner, J. W., 1952, New data of synthesis of uranium minerals: *in* U.S. Atomic Energy Comm. RMO-983, Annual report for July 1, 1951 to June 30, 1952, 26 p.

Experimental studies of synthesis of uranium minerals under various conditions. Subjects include uranyl compounds made hydrothermally; uranyl compounds made between room temperature and 100°C; pitchblende (uraninite) synthesis between room temperature and 217°C.

98 Gruner, J. W., 1953, Syntheses of uranium minerals at room and elevated temperatures (abs.): Am. Mineralogist, v. 38, p. 342.

Experimental studies of synthesis of various uranium minerals. Synthesis of pitchblende (uraninite) is at temperatures of 50° to 112°C by reduction of uranyl ions with H^2S ferrous ions.

99 Gruner, J. W., 1954a, Further experiments on the synthesis of uraninite: *in* U.S. Atomic Energy Comm. RME-3094, pt. 3, Annual report for April 1, 1953 to March 31, 1954, p. 28-30.

Studies conducted in connection with the question of temperature required for the formation of uraninite.

100 Gruner, J. W., 1954b, The problem of the primary ores of the Colorado Plateau: *in* U.S. Atomic Energy Comm. RME-3094, pt. 4, Annual report for April 1, 1953 to March 31, 1954, p. 31-32.

Genesis of yellow oxidized uranium ores of the Colorado Plateau in recognition that carbonaceous material is nearly always associated with the ores and that black ores are common. Attention is directed to implications of this association, organic matter and ore, on the character of the chemical environment of primary mineralization. Includes analyses of organic matter in ore, two of which are samples from deposits of Grants uranium region.

101 Gruner, J. W., 1954c, The origin of the uranium deposits on the Colorado Plateau and adjacent regions: Mines Mag., v. 44, no. 3, p. 53-56.

Genesis of uranium ores of the Colorado Plateau, including Grants uranium region. Subject considers new observations from field and experimental studies. Hypothesis of origin is suggested. Subjects include distribution of ores, relation of yellow oxidized ores to black ores; chemical and physical properties of uranium minerals; also source of uranium, transporting medium (character and migration), function of organic matter associated with ore (reducing

agent), and history of tectonic activity. The hypothesis suggests that black ores originated from several stages of migration and accumulation of uranium, that yellow oxidized ores are derived from black ores, and that distribution of yellow ores is related to the modern topographic surface.

102 Gruner, J. W., 1954d, The uranium mineralogy of the Colorado Plateau and adjacent regions: *in* Utah Geol. Society, Guidebook to the Geology of Utah, no. 9, Uranium deposits and general geology of southeastern Utah, p. 70-77.

Summarizes information pertaining to mineralogy of uranium deposits of the Colorado Plateau and adjacent areas, including localities of Grants uranium region. Subjects include geochemistry of uranium; minerals of deposits and manner of occurrence; unoxidized mineral deposits; change of black to yellow ores; gangue minerals. To place in historical context, paper reports information that is part of the process of general recognition of the genetic connection of the yellow, oxidized ores and the black, unoxidized ores of the Plateau. Author remarks: "Only 3 or 4 years ago it was unknown that most yellow oxidized ores would grade into unoxidized ones of a very different appearance where a thick, impervious cover and abundant carbonaceous material in the sediments protected the uranium and associated sulfides from oxidation."

Illustrations: table of uranium minerals; table of vanadium minerals in sedimentary rocks.

103 Gruner, J. W., 1955, A comparison of four important areas of black uranium ore mineralization in Utah, New Mexico, and Wyoming in the Chinle, including Shinarump, Brushy Basin (Morrison), and Wind River formations: *in* U.S. Atomic Energy Comm. RME-3020, Annual report for April 1, 1954 to March 31, 1955, p. 6-15.

Paper is an early edition of Gruner, 1956a; see below.

104 Gruner, J. W., 1956a, A comparison of black uranium ore deposits in Utah, New Mexico and Wyoming: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 203-205.

Compares important primary uranium deposits of western states, including Morrison deposits of the central part of Grants uranium region (Poison Canyon and Mesa Top mines of the Poison Canyon trend, Ambrosia Lake district). Study recognizes similarities of host rock, mineralogy, textural relations (paragenesis), and apparent ore processes in deposits of widely separated areas. Considers migration of mineralizing solutions by stratigraphic and structural controls of migration and characteristics of the solutions.

Illustrations: chart comparing deposits.

105 Gruner, J. W., 1956b, Concentration of uranium in sediments by multiple migration-accretion: Econ. Geology, v. 51, p. 495-520.

Genesis of uranium deposits in sedimentary rocks of western states, the uranium province of the United States, including Grants uranium region. Paper was written when expansion of areas of uranium occurrence brought about by new discoveries appeared to make untenable hydrothermal hypothesis of origin. Subjects include effects of chemical properties of uranium; valence states of ionized uranium, relative stability of the uranous ion, Eh of uranous ion, influence of vanadium as an additive to uranous and uranyl solutions, the solubility and reactivity of the uranyl ion and solubility of uranyl compounds, affinity of uranium ions for organic material, and the solubility of complexed carbonates of uranium; results of new experimental study of solubility of uranium compounds; geologic observations; distribution of mineralization with respect to certain structures and textures; mineralogic observations on black ores; mineralogic observations on yellow ores; quantity of uranium required to form deposits and bearing on validity of a hydrothermal hypothesis of origin; bearing of determinations of absolute age of ore on validity of a hydrothermal hypothesis; availability of uranium in igneous and other rocks; solubility and transportability of uranium ions; indicated chemical conditions of formation of ore. Author proposes Multiple Migration-Accretion Hypothesis of origin of uranium ore, which is formation of ore through several cycles of oxidation-solution-migration-precipitation.

Illustrations: tables of experiments on solubility of various uranium compounds.

106 Gruner, J. W., 1956c, Progress report no. 11 for period April 1 to October 1, 1956: U.S. Atomic Energy Comm. RME-3145, 14 p.

Field observations of relations in uranium deposits of western states. Subjects include field work in Wyoming, Montana, and the Dakotas; field work in Colorado, Utah, Arizona, New

Mexico and Texas; additional data on uranium (tricarbonate solution); also general similarities of mineralogy and geochemistry of uranium deposits, implying that the deposits are of similar origin.

Illustrations: table of analyses.

107 Gruner, J. W., 1957a, Experiments on the solubility of U and V compounds in bicarbonate solutions of Na, Ca, and Mg in the presence of excess CO_2: *in* U.S. Atomic Energy Comm. RME-3148, pt. 2, Annual report for April 1, 1956 to March 31, 1957, p. 29-34.

Experimental studies of solubility of U and V compounds in bicarbonate solutions; of action of humic acid and liquid-saturated hydrocarbons on uranium in solutions. Supplemental to similar investigations reported in Gruner, 1956 ("Multiple migration-accretion").

Illustrations: table of experiments.

108 Gruner, J. W., 1957b, Experiments which show the improbability of reduction and precipitation of uranous oxide from uranyl solutions by pyrite, marcasite, or chalcopyrite at room temperature: *in* U.S. Atomic Energy Comm. RME-3148, pt. 4, Annual report for April 1, 1956 to March 31, 1957, p. 49-51.

Experimental study of the effectiveness of pyrite and related minerals to reduce and precipitate uranous oxide from uranyl solutions. Investigations conducted especially to check similar studies reported earlier by others.

109 Gruner, J. W., 1959, Final report for June 1949 to the end of contract, June 30, 1958: U.S. Atomic Energy Comm. RME-3159, 39 p.

Review of investigations (undertaken by author and associates) of uranium deposits of the Colorado Plateau and adjacent areas, including Grants uranium region. Subjects include deposits in Todilto Limestone, with discussion of origin of mineralization; color changes and review of possible chemical processes involved in the alteration of color; clays and mudstones; comparison of four important areas of black uranium ores in Utah, New Mexico, and Wyoming with attention to similarity of deposits despite separation by great distance; conclusions regarding processes that concentrated uranium in sediments (the "Multiple Migration-Accretion" hypothesis); chemical experiments; identification of minerals from properties in the western states.

Illustrations: table of solubility experiments; table of comparison of four widely separated areas of uranium mineralization (black ores); table indexing by locality published identifications of minerals.

110 Gruner, J. W., and Gardiner, Lynn, 1951, A preliminary report on the geology, mineralogy and origin of the uranium deposits of the Grants district, McKinley and and Valencia Counties, New Mexico: *in* U.S. Atomic Energy Comm. RMO-771, pt. 1, Annual report for July 1, 1950 to June 30, 1951, p. 1-20.

Study of Todilto Limestone and uranium deposits of Grants area, central part of Grants uranium region. Subjects include stratigraphy of the limestone; alteration of limestone; stylolitic surfaces in the limestone; structural features in the limestone; uranium deposits in the limestone; depositional environment of Todilto Limestone; origin of crinkles in upper part of limestone; origin of fluorite; origin of pitchblende; genesis of deposits. Authors conclude that the uranium is "syngenetic with the limestone in the sense that uranium was precipitated in a periodically slightly turbid fresh-water sea." Paper was written before recognition of the genetic connection of the black and yellow ores of the Colorado Plateau.

111 Gruner, J. W., and Gardiner, Lynn, 1952, Mineral associations in the uranium deposits of the Colorado Plateau and adjacent regions with special emphasis on those in the Shinarump Formation: *in* U.S. Atomic Energy Comm. RMO-566, pt. 3, Annual report July 1, 1951, to June 30, 1952, 40 p.

Identifies minerals and organic matter from uranium deposits in Colorado, Utah, Arizona, and New Mexico. Lists minerals and localities of the deposits "in such a manner that a comparison of the deposits and districts becomes possible and profitable." Work stems from initial investigations of uranium mineralization on the Colorado Plateau by the U.S. Atomic Energy Commission. Authors mention following items of historical interest: tentative naming of coffinite; designating mineral belt between Albuquerque and Gallup as new (now Grants uranium region); possible function of carbonaceous matter in ore-forming processes; deposits

of Grants uranium region: unnamed deposits of the Todilto, Jackpile mine, Silver Spur mine, Poison Canyon mine, and Desanti mine.

112 Gruner, J. W., and Knox, J. A., 1957, Minerals identified from properties in Arizona, Colorado, Montana, New Mexico, South Dakota, Texas, Utah, and Wyoming: *in* U.S. Atomic Energy Comm. RME-3148, Annual report for April 1, 1956 to March 31, 1957, p. 35-48.

Identifies minerals from various localities in western states. Includes minerals from uranium deposits of Grants uranium region, Blue Peak and Poison Canyon mines (deposits of the Poison Canyon trend, Ambrosia Lake district, central part of region), Dysart shaft (a deposit of the Ambrosia Lake trend, Ambrosia Lake district), and Jackpile mine (Laguna district, eastern part of region).

113 Gruner, J. W., and Smith, D. K., Jr., 1954, Ninth progress report for period April 1 to October 1, 1954: U.S. Atomic Energy Comm. RME-3103, 10 p.

Field observations of deposits in South Dakota, Wyoming, New Mexico, and Arizona. Includes mention of occurrence of wood in the peat stage of the Westwater Canyon Member of Morrison Formation in the shaft sunk on Mesa Top Claims.

114 Gruner, J. W., and Smith, D. K., Jr., 1955a, The problem of coffinite: *in* U.S. Atomic Energy Comm. RME-3020, Annual report for April 1, 1954 to March 31, 1955, p. 16-24.

Early experimental study of coffinite. Names the Jackpile, Woodrow Pipe, Windwhip, Poison Canyon, and Mesa Top mines–Morrison deposits of Grants uranium region–as the most important occurrences of the mineral. Subjects include data on coffinite; experiments at elevated temperature, unit cell dimensions. Discusses composition and structure of coffinite and explanation of why the mineral is generally found in a finely divided state.

Illustrations: table of analyses.

115 Gruner, J. W., and Smith, D. K., Jr., 1955b, Some additional determinations of minerals of the Colorado Plateau: *in* U.S. Atomic Energy Comm. RME-3020, Annual report for April 1, 1954 to March 31, 1955, p. 34-37.

Identifications of minerals from uranium deposits of various areas including Grants uranium region (Poison Canyon, Mesa Top, Woodrow, Jackpile, Windwhip, and Diamond No. 2 deposits).

116 Gruner, J. W., and others, 1953a, Syngenetic versus hydrothermal hypothesis for the origin of the uranium deposits of the Colorado Plateau: *in* U.S. Atomic Energy Comm. RME-3044, pt. 6, Annual report for July 1, 1952 to March 31, 1953, p. 41-58.

Discussion of genesis of uranium deposits of the Colorado Plateau, including Grants uranium region. Authors review thinking of the time. Accepted principle and generally held questions were: uranium in deposits concentrated by ground waters not warmer than the earth's existing thermal gradient would indicate; source of uranium in ground water may have been hydrothermal solutions associated with Tertiary igneous intrusions or may have been the host sediments. Authors suggest that there is good reason to believe that the uranium was carried in somewhat acidic solutions high in $SO_4^{=}$ ions and that where these were neutralized, precipitation resulted. Also that uranium ore is universally associated with organic matter, uraninite can form at low temperature, and deposits are distributed over a broad geographic region.

Illustrations: table comparing chemical compositon of sedimentary rocks and average composition of igneous rocks; table listing elements found in coal ashes.

117 Gruner, J. W., and others, 1953b, Eighth progress report for period April 1 to October 1, 1953: U.S. Atomic Energy Comm. RME-3060, 9 p.

Progress reports of various uranium investigations: field, mineralogical, clay, alteration of plant fossils, and laboratory. Especially treated are occurrences of black uranium ore in various deposits on the Colorado Plateau, including Grants uranium region, Todilto and Morrison mineralization of the Grants area and Morrison mineralization of the Laguna district.

118 Gruner, J. W., and others, 1954, Mineral associations in the uranium deposits of the Colorado Plateau and adjacent regions–interim report: U.S. Atomic Energy Comm. RME-3092, 48 p.

Identifications of minerals and other substances from uranium deposits of the Colorado Plateau, including Grants uranium region. Information is tabulated under names of areas: Utah areas (San Rafael Swell region, White Canyon region, inter-river region, Moab region, and other Utah localities); Arizona areas; Colorado areas; New Mexico areas. Deposits appear below the name of the appropriate area and identifications of minerals and other substances below the name of the appropriate deposit. Deposits of Grants uranium region are unnamed Todilto claims, Poison Canyon mine, Jackpile mine, Woodrow claim, Silver Spur mine, and Desanti mine.

119 Harmon, G. F., and Taylor, P. S., 1963, Geology and ore deposits of the Sandstone mine, southeastern Ambrosia Lake area, *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 102-107.

Studies geology and uranium deposits of Sandstone mine, Ambrosia Lake district, central part of Grants uranium region. Deposits are in Westwater Canyon Member of Morrison Formation and are part of Ambrosia Lake trend. Deposits of the mine are of both primary and redistributed types. Subjects include local (mine area) Morrison stratigraphy, divisions, thicknesses, contacts, lithology; local structure, faults, lesser fractures, and attitude of beds; form, dimensions, and orientation of ore bodies; ore boundaries; stratigraphic distribution of deposits, positions in the Westwater; distribution of mineralization; types of carbonaceous material and distribution of mineralization with respect to carbonaceous material; black barren material, kinds, composition, and distribution with respect to ore; distribution of calcite with respect to ore; general characteristics of primary and redistributed ore bodies; thicknesses and colors of ore, and U/V ratios; mineral assemblages, ore and accessory; and sedimentary controls of ore deposition, thickness of sandstone and mudstone structures. Also control of ore deposition by a fluid interface and control of ore deposition by fractures. Ore is said to be offset by faults, and fractures influencing mineralization are said not to have been observed.

Illustrations: large-scale mine wall map; large-scale geologic sections of ore bodies.

120 Harshbarger, J. W., and others, 1951, Jurassic stratigraphy of the Navajo country: *in* New Mexico Geol. Soc. Guidebook 2nd Field Conf., South and west sides of the San Juan basin New Mexico and Arizona, p. 95-99.

Describes stratigraphy of the Jurassic section (Wingate-Morrison, inclusive) of the western part of Grants uranium region and adjacent areas to the west; includes definition of Cow Springs Sandstone (Jurassic). Presentation is preliminary to the publication of Harshbarger and others, 1957; see below.

Illustrations: isometric fence diagram of Jurassic rocks in Navajo Reservation; measured section.

121 Harshbarger, J. W., and others, 1957, Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo Country: U.S. Geol. Survey Prof. Paper 291, 74 p.

Study of stratigraphy of the section, Wingate (Triassic)—Morrison (Jurassic) inclusive, of northeastern Arizona and bordering areas of Utah and New Mexico, including westernmost part of Grants uranium region. Treatment separates section into four main parts, from lower to upper: Glen Canyon Group; San Rafael Group; Cow Springs Sandstone; and Morrison Formation. Each formation is defined by age; stratigraphic nomenclature; contacts; divisions; thicknesses; areal distribution; facies; lithology, including texture and mineral composition of chief rock types; fossils; origin of divisions, especially depositional environments. Topics include lower boundary of Glen Canyon Group; sedimentational history of Glen Canyon Group; evidence for the age assignment of Glen Canyon Group; lower boundary of San Rafael Group; sedimentational history of San Rafael Group, the Jurassic-Cretaceous boundary.

Illustrations: fence diagrams; sketch maps showing hypothetical physiography of region at various times during deposition of the sequence; maps showing approximate depositional areas of various formations; photographs; measured stratigraphic sections.

122 Harshbarger, J. W., and others, 1958, Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo country: *in* New Mexico Geol. Soc. Guidebook 9th Field Conf., Black Mesa basin, p. 98-114.

Condensed version of the stratigraphic study published in 1957 as U.S. Geol. Survey Prof. Paper 291. Formations considered are those of the Glen Canyon and San Rafael groups and the Morrison Formation. Area of study is northeastern Arizona and immediately adjoining

small parts of Utah and New Mexico. The New Mexico portion includes the westernmost part of Grants uranium region.

Illustrations: chart of stratigraphic nomenclature; photographs; fence diagrams.

123 Haun, J. D., and Kent, H. C., 1965, Geologic history of Rocky Mountain region: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1781-1800; also 1970, *in* Natl. Assoc. Geol. Teachers, southwest section Guidebook, Four Corners, Colorado Plateau, Central Rocky Mountain region, p. 1-20.

Sedimentational history in the Rocky Mountain region to outline the major events. The region includes the Colorado Plateau and Grants uranium region. Treatment of sedimentation in the region is by Era and Period, Precambrian through Cenozoic.

Illustrations: paleogeographic maps; worm's-eye maps; distribution maps; isopach maps; facies maps; various diagrammatic and schematic sections; map of Early Tertiary tectonic framework of region; distribution map of Cenozoic igneous rocks; diagram summarizing depositional history.

124 Hazlett, G. W., and Kreek, Justin, 1963, Geology and ore deposits of the southeastern part of the Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 82-89.

Reviews geology of eastern part of Ambrosia Lake trend in introduction to papers in New Mexico Bureau Mines Mineral Resources Memoir 15 (1963) on Ann Lee, Sandstone, and Cliffside mines of the area. The Ambrosia Lake trend is in the northern part of Ambrosia Lake district, central part of Grants uranium region. Deposits are in Westwater Canyon Member of Morrison Formation. Subjects include local Morrison stratigraphy; local structure; form of distribution of uranium deposits; stratigraphic distribution of deposits; distribution of deposits with respect to sedimentologic variations; controls of ore deposition; mineral assemblages.

Illustrations: small-scale geologic map; large-scale geologic sections; composite columnar section; correlation of electric logs with Westwater stratigraphy; table showing stratigraphic distribution of ore within the Westwater.

125 Heinrich, E. W., 1958, Mineralogy and geology of radioactive raw materials: New York, McGraw-Hill Book Co., Inc., 654 p.

Summary and coordination of scientific and technical results stemming from the search for uranium in the 1950s. Author describes the intensity of these efforts to discover uranium during this period as "unprecedented in the history of minerals exploration." Information in the book comes from observations of relations in many parts of the world, including deposits of Grants uranium region. Subjects include mineralogy of radioactive minerals; radioactive mineral deposits; syngenetic deposits in igneous rocks; radioactive pegmatite deposits; carbonatites and related deposits; pyrometasomatic and other high intensity, hydrothermal deposits; mesothermal deposits; epithermal deposits; epigenetic stratiform deposits in sedimentary rocks; uraniferous phosphorites; uraniferous black shales; placer deposits of radioactive minerals; radioactive hydrocarbons; deposits formed by weathering and ground water action. Subjects of Grants uranium region include deposits in Todilto Limestone; deposits in Morrison Formation.

Illustrations: maps; photographs; tables.

126 Hilpert, L. S., 1961, Structural control of epigenetic uranium deposits in carbonate rocks of northwestern New Mexico: *in* U.S. Geol. Survey Prof. Paper 424-B, Short papers, p. 5-8.

Study of uranium deposits in limestones—Madera (Pennsylvanian), San Andres (Permian), Todilto (Jurassic)—of northwestern New Mexico. The Todilto deposits are in central and eastern parts of Grants uranium region. Subjects include mineral assemblages; form of deposits; intraformational folds of the Todilto; distribution of mineralization with respect to Todilto folds and to structures of the other limestones; age of structural features in the several formations; age of mineralization in these formations; the chief control of localization of deposits. Conclusion reached is that chief controls of mineralization are tectonic structures and only deformed rocks are good host rocks for epigenetic uranium deposits.

Illustrations: map of deposits.

127 Hilpert, L. S., 1963, Regional and local stratigraphy of uranium-bearing rocks: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 6-18.

Stratigraphy of the Jurassic-Cretaceous, Entrada-Dakota section of Grants uranium region. Formations, from lower to upper, are Entrada, Todilto, Summerville, Bluff, Morrison, and Dakota. Discussion of each formation includes development of nomenclature; age of formation; regional distribution and relations; local (Grants uranium region) stratigraphy with divisions, variations in distribution of units, thicknesses, contacts, lithologies, and distribution of uranium mineralization; depositional environments of formations; relations of the Entrada Sandstone and underlying Wingate Sandstone.

Illustrations: chart describing stratigraphy of the local section and distribution of uranium mineralization; charts illustrating development of stratigraphic nomenclature; figure illustrating alternative interpretations of Wingate-Entrada relations between Ambrosia Lake and Laguna; small-scale geologic section of stratigraphic relations in the Morrison between Ambrosia Lake and Laguna.

128 Hilpert, L. S., 1969, Uranium resources of northwestern New Mexico: U.S. Geol. Survey Prof. Paper 603, 166 p.

Comprehensive review of geology of uranium of northwestern New Mexico, including Grants uranium region. Subjects are: stratigraphy; structural geology; geologic history; uranium deposits; distribution of elements in the ores; uranium resources and areas recommended for exploration. The section on uranium deposits is further divided; chief topics are: peneconcordant deposits in sandstone—in rocks of Pennsylvanian, Permian, and Triassic age, in Morrison Formation of Jurassic age, in rocks of Cretaceous age, and in rocks of Tertiary and Quaternary age; peneconcordant deposits in Todilto Limestone and adjacent formations; peneconcordant deposits in shale and coal; and vein deposits. Morrison deposits are treated by district; principally the Ambrosia Lake, Laguna, Gallup, Shiprock, and Chuska districts. Grants uranium region includes the first three. Discussion of each district includes: local Morrison stratigraphy, local structural geology, form of deposits, mineral assemblages, stratigraphic relations of deposits, structural relations of deposits, and color relations of host rocks. Also of Grants uranium region are the deposits of Todilto and adjacent formations. Todilto subjects are: Todilto stratigraphy; structural features bearing on occurrence of uranium deposits; form and dimensions of deposits; mineral assemblages; stratigraphic relations of deposits; and structural relations of deposits. The section on distribution of elements in the ores treats: elements in Morrison ores; and elements in Todilto Formation (including elements that decrease in concentration away from ore, elements that increase in concentration away from ore, elements concentrated between ore and barren ground, and elements in the gypsum unit). Author considers genesis of deposits: age of mineralization; geologic controls of mineralization—including stratigraphic, sedimentologic, and structural; and source of uranium (especially for deposits in Upper Jurassic rocks)—receiving consideration in this connection are the nature of transporting solutions, hydrologic conditions of migration, and direction of migration of the uranium-bearing solutions.

Illustrations: small and large-scale geologic maps and sections; generalized correlation chart of the principal stratigraphic units in northwestern New Mexico; tables of analyses of mill-pulp samples; tables showing concentrations of elements in various sample groups; tables listing uranium deposits by county; tables of uranium areas classified by age and type of host rock.

129 Hilpert, L. S., and Freeman, V. L., 1956, Guides to uranium deposits in the Morrison Formation, Gallup-Laguna area New Mexico: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 299-302.

Outlines stratigraphy of important ore-bearing sandstones of Morrison Formation of Grants uranium region, the Poison Canyon and Jackpile sandstones, divisions of the Morrison known to be commonly mineralized at the date of writing. The paper also gives a sketch of ore guides, stratigraphic features common to mineralized parts of the units.

Illustrations: small-scale geologic sections taken through mineralized areas of Brushy Basin Member of Morrison Formation.

130 Hilpert, L. S., and Moench, R. H., 1958, Uranium deposits of the southern part of the San Juan basin, New Mexico: United Nations Internat. Conf. Peaceful Uses Atomic Energy 2nd Proc., Geneva, v. 2, p. 527-538.

This is a shortened version of the paper of the same title published in 1960 by Hilpert and Moench; see below.

131 Hilpert, L. S., and Moench, R. H., 1960, Uranium deposits of the southern part of the San Juan basin, New Mexico: Econ. Geology, v. 55, p. 429-464.

Study of uranium deposits of Grants uranium region. Treatment emphasizes mineralization in Todilto and Morrison Formations and includes description of specific deposits. Authors include the mineralization of Entrada and Dakota Formations in overall considerations. Subjects include local stratigraphy; structural geology elements of pre-Dakota age (including intraformational folds of the Todilto and pipelike collapse structures of the Morrison), elements of post-Dakota age, and history of local deformation; igneous geology; ore deposits–distribution (relation to particulars of stratigraphy, sedimentology, structural geology, and relation to igneous rocks, and carbonaceous material), and mineral assemblage (identification and description of occurrence of ore and accessory minerals). Authors consider structural features; stratigraphic features; ore deposits.

Illustrations: small- and large-scale geologic and other maps; numerous small- and large-scale diagrammatic and other geologic sections and sketches; photograph.

132 Hohne, F. C., 1963, Production geology methods at the Kermac mines: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 247-255.

Description of methods practiced by Kermac in developing uranium deposits of Ambrosia Lake trend, Morrison deposits of central part of Grants uranium region. Subjects include plan of surface drilling used to collect information for designing the basic mine layout; procedures of underground exploration followed in collecting information for planning additional mine structures; geologic and engineering procedures followed in developing stopes and duties of the grade control engineer; general duties of the mine geologist; structure of mine organization.

Illustrations: include various longhole arrangements; mine maps (plan views) of grade control data; representation of the plan of stope development; diagrammatic section through a shrinkage stope; diagrammatic section through a stack-type ore body illustrating procedures of development and stoping.

133 Hoskins, W. G., 1963, Geology of the Black Jack No. 2 mine, Smith Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 49-52.

Study of geology and uranium deposits of Black Jack No. 2 mine, Smith Lake area, western part of Grants uranium region. Deposits are in Poison Canyon Sandstone of Brushy Basin Member of Morrison Formation. Subjects include local stratigraphy and structural geology; form of deposits; position of ore with respect to the water table; general state of oxidation of ore minerals (unoxidized). Author considers controls of ore deposition–stratigraphic, sedimentologic, and possible control through the occurrence and action of carbonaceous material (black, greasy matter).

Illustrations: small-scale structure map of the general area; large-scale plan map of the mine; large-scale geologic sections; diagrammatic section showing positions of ore-bearing sandstone.

134 Hunt, C. B., 1938, Igneous geology and structure of the Mount Taylor volcanic field, New Mexico: U.S. Geol. Survey Prof. Paper 189-B, 80 p.

Geology of Mount Taylor volcanic field, in central and eastern parts of Grants uranium region. Subjects include geography, geomorphic location, land forms, drainage, and climate and vegetation; late Tertiary and Quaternary history (a summary), chronology of events, and age assignments; volcanic activity, chronology, the Mount Taylor volcano (rocks of the explosively eruptive sequence), sheet basalt (various flows, vents, and necks), basalt dikes, origin of breccia, and Recent flows; structural geology, overall structural relations of the volcanic field, particulars of the Colorado Plateau portion of the field (McCarty syncline, minor folds within Syncline, folds northwest of Syncline, gentle warping east of Syncline), particulars of the Basin and Range portion of the field (structural relations of the field, folds, and faults), age of the deformation, and possible significance of the structural features; relation of volcanic activity and structural movement; genesis of folds and faults.

Illustrations: small-scale (1/125,000), colored geologic map (topographic base) of Mount Taylor field; drainage map; photographs; sketches; block diagrams; diagrammatic view and sections.

135 Hunt, C. B., 1956, Cenozoic geology of the Colorado Plateau: U.S. Geol. Survey Prof. Paper 279, 99 p.

Summary of Cenozoic geology of the Colorado Plateau and historical interpretation of the data. Describes features of Grants uranium region specifically. Author considers the Plateau as a unit block and a distinctive province comprised of various structural elements in his study of

the development of geology of the region. Subjects include Precambrian basement rocks; summary of Paleozoic and Mesozoic stratigraphy; Cenozoic igneous rocks; structural geology; physiography; and Cenozoic history of the Plateau.

Illustrations: small-scale maps and geologic sections of various kinds; correlation charts; diagrammatic sketches of various features; diagrams showing composition of igneous rocks; figures portraying tectonic features and drainage patterns of the Plateau at various periods in the Cenozoic.

136 Hunt, C. B., and Dane, C. H., 1954, Map showing geologic structure of the southern part of the San Juan basin, New Mexico: U.S. Geol. Survey Oil and Gas Inv. Map, OM 158.

Small-scale, geologic structure map of the southern part of San Juan basin, including Grants uranium region. Map was originally published in 1933 as a compilation of earlier data. Shows structure with 100-ft contours of the base of Dakota Sandstone, and lines marking faults. Stratigraphic information for the outcrop section provided in a chart.

137 Huttle, J. B., 1958, U_3O_8 production now under way at Ambrosia Lake district: Eng. and Mining Jour., v. 159, no. 7, p. 87-92.

Review of development of the uranium industry in the Grants area, central part of Grants uranium region. Subjects include geology of Westwater ore bodies at Ambrosia Lake; history of uranium exploration and development of mining and milling at Ambrosia Lake; local mining methods and equipment.

Illustrations: photographs.

138 Isachsen, Y. W., and others, 1955, Age and sedimentary environments of uranium host rocks, Colorado Plateau: Econ. Geology, v. 50, p. 127-134.

Distribution of uranium deposits in sedimentary rocks (chiefly) of the Colorado Plateau, including deposits of Grants uranium region. Authors describe treatment as follows: "In order to present a general picture of the variety of uranium occurrences, one deposit is described for each rock unit in which strong mineral concentration or ore has been discovered on the Colorado Plateau. In addition, an estimate of the production potential for the stratigraphic unit is included in each description, unless otherwise specified." Deposits occur in sedimentary units of almost every geologic age from middle Pennsylvanian to middle Tertiary, and the host rocks reflect all major sedimentary environments except glacial. Authors conclude that the deposits are of epigenetic origin.

Illustrations: stratigraphic table of host formations.

139 Jensen, M. L., 1958, Sulfur isotopes and the origin of sandstone-type uranium deposits: Econ. Geology, v. 53, p. 598-616.

Results of analysis for sulfur isotopes in sulfide minerals associated with uranium deposits in sedimentary rocks of the Colorado Plateau and Wyoming; comparison of these isotope ratios with ratio of the standard of troilite and with ratios found in sulfides of known origin. Characteristics of the isotope ratios from uranium deposits and an origin for their peculiarity are discussed. An hypothesis is suggested that considered principally the precipitating agent but also a source of uranium and a sequence of events. The study includes a few analyses from deposits of Grants uranium region.

Illustrations: table of isotope ratios; figures comparing isotope ratios from sulfides of various sources and deposits.

140 Jensen, M. L., 1963, Sulfur isotopes and biogenic origin of uraniferous deposits of the Grants and Laguna districts: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 182-190.

Studies isotopic composition of the sulfur of minerals associated with uranium deposits of Todilto and Morrison formations of Grants uranium region. Reviews relevant basic concepts of chemistry; characteristics of the isotopic composition of sulfur of biogenic origin and the theory of origin of the characteristics; characteristics of the isotopic composition of sulfur of magmatic hydrothermal origin and the theory of origin of the characteristics. Describes experiments with production of biogenic sulfur; isotopic analyses of sulfur from mineral specimens from deposits of the region, sandstone and limestone deposits of the Grants area, and sandstone, limestone, and pipe deposits of the Laguna area; isotopic analyses of sulfur from mineral specimens from deposits of magmatic hydrothermal origin. Also includes consideration of origin (biogenic) of sulfide minerals from deposits of the region; reviews previously suggested hypothesis of origin of deposits (Jensen, 1958); compares isotopic analyses of sulfur of minerals from deposits of the region with those of sulfur from minerals of

sandstone-type deposits located elsewhere on the Colorado Plateau and in Wyoming; discusses applicability of Jensen's hypothesis to the question of origin of the stacked deposits of Ambrosia Lake district; discusses apparent problems with Jensen's hypothesis when applied to origin of the region deposits in Jurassic hosts. Author concludes that anaerobically produced hydrogen sulfide plays a significant role in the localization of deposits.

Illustrations: table of sample data; figure comparing biogenic and hydrothermal sulfur isotopes; figure representing results of an experiment with production of biogenic sulfur and hydrogen sulfide.

141 Jobin, D. A., 1956, Regional transmissivity of the exposed sediments of the Colorado Plateau as related to distribution of uranium deposits: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 207-211.

Transmissivity characteristics of formations of the Plateau region and relations of these characteristics to distribution of uranium deposits; formations of Grants uranium region. Treatment includes description of form of deposits; classification of formations and description of respective characteristics of transmissivity; consideration of influence of transmissivity on the distribution of deposits.

Illustrations: small-scale transmissivity maps; chart correlating the intrinsic transmissivity of formations with distribution of deposits.

142 Jobin, D. A., 1962, Relation of the transmissive character of the sedimentary rocks of the Colorado Plateau to the distribution of uranium deposits: U.S. Geol. Survey Bull. 1124, 151 p.

Studies transmissive characteristics of formations of the Colorado Plateau and the relations of these characteristics to the distribution of uranium deposits. In Grants uranium region investigations include relations in Todilto, Morrison, and Dakota Formations. The studied section for the Plateau is the sequence Abo-Mesaverde of Permian to Cretaceous age. Chief topics include horizontal transmissivity of the hydrologic units; vertical transmissivity of the section; uranium distribution in relation to the transmissive character of the host rock. Topics considered especially for the major uranium-producing hydrologic units include: causes of variations in the thickness of hydrologic units; causes of variations in permeability of hydrologic units, that is, variations in texture, thickness, and distribution of lithologic components of units; significance of patterns of distribution of horizontal transmissivity; relation of trends of horizontal permeability and transmissivity to directions of sediment transport and direction of sediment source; significance of the distribution of deposits with respect to transmissive characteristics of units, especially to the standard deviation of permeability and of thickness of units; and classification (transmissive criteria) of ground favorable for uranium deposits.

Illustrations: isopach, isopermeability, isotransmissivity, small-scale maps; maps of areal distribution; maps of distribution of uranium deposits with respect to transmissive characteristics of units; illustrations of size distribution of deposits; tables comparing transmissive characteristics of various genetic classes of units; tables of data for statistical analyses.

143 John, E. C., and West, S. W., 1963, Ground water in the Grants district: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 219-221.

Describes ground-water characteristics of aquifers of the central part of Grants uranium region. Stratigraphic divisions include Glorieta Sandstone and San Andres Limestone of Permian age; Chinle Formation of Triassic age; San Rafael Group and Morrison Formation of Jurassic age; Dakota Sandstone of Cretaceous age; and alluvium and basalt of Quaternary age. Chief aquifers: Glorieta Sandstone, San Andres Limestone, Westwater Canyon Member of Morrison Formation, Dakota Sandstone, and alluvium and basalt. Items include sedimentary characteristics influencing transmissibility of divisions; depth of water at various localities; yield obtained from aquifers; quality of water in various aquifers; difficulties caused by ground water in mining.

144 Johnston, G. C., 1963, Subsidence and pillar recovery in the west area of the Marquez mine: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 256-263.

Studies problems in underground mining during the production phase of development at the Marquez mine, a Morrison uranium deposit of Poison Canyon trend, Ambrosia Lake district, central part of Grants uranium region. Alterations of the natural environment brought about by mining are said to have led to unforeseen caving action, pillar settling, and bottom

heaving. Subjects include local geologic setting; lithology of ore zone; natural mine environment; development phase of mining; original plan of retreat (production) phase of mining; alterations in geologic and water conditions accompanying progress of retreat toward shaft; changes in stability of mine; immediate remedial action taken; analysis of problems; methods of stabilization and continued mining; natural and imposed conditions that led to subsidence.

Illustrations: geologic section; large-scale maps in plan view of the mine; map areas of subsidence in the mine; schematic maps illustrating mining methods; figure showing pillar design.

145 Keller, W. D., 1962, Clay minerals in the Morrison Formation of the Colorado Plateau: U.S. Geol. Survey Bull. 1150, 90 p.

Studies clay minerals of Morrison Formation of the Colorado Plateau, including Grants uranium region. Subjects include stratigraphy and lithology of divisions of the Morrison; distribution of clay minerals. Considers argillation of Brushy Basin Member; coloration of mudstone of the Morrison; geologic history during Morrison time (as inferred from clay mineralogy); clay minerals as specific guides to ore; clay minerals as sedimentary facies; relation of clay minerals to genesis of uranium ore.

Illustrations: correlation of measured stratigraphic sections on the Plateau, clay-mineral compositions indicated; photographs and photomicrographs; thermograms and diffractograms; tables of analyses.

146 Kelley, V. C., 1951, Tectonics of the San Juan basin: *in* New Mexico Geol. Soc. Guidebook 2nd Field Conf., South and west sides of the San Juan basin, New Mexico and Arizona, p. 124-131.

Study of major structural features around San Juan basin, including Grants uranium region. Subjects include chief tectonic elements comprising the region—uplifts, structural platforms, monoclines, and the Central basin. Author defines and delineates individual elements and describes their boundaries and form. Describes Rio Grande fault belt, structural boundary of the southeastern part of San Juan basin. Subjects include tectonic history of region; origin of the Central basin; source and configuration of stresses forming comparatively minor structures.

Illustrations: small-scale map of structural elements of region; small-scale tectonic map of part of San Juan basin and Rio Grande trough.

147 Kelley, V. C., 1955a, Monoclines of the Colorado Plateau: Geol. Soc. America Bull., v. 66, p. 789-804.

Monoclines of the Colorado Plateau; structural elements of Grants uranium region. Subjects include definition of the term monocline; structural significance of monoclines; characteristics of the monoclines; age of formation; regional relations; theories of genesis proposed by others. Considers genesis of monoclines: deforming stress, type, possible orientations, and origins. Paper contributes the concept that features observed along monoclines are homologous and that monoclines originated through several stages of development.

Illustrations: small-scale structure maps; geologic section; diagrammatic figures.

148 Kelley, V. C., 1955b, Regional tectonics of the Colorado Plateau and relationship to the origin and distribution of uranium: University New Mexico Publications in Geology, no. 5, 120 p.

Studies major structure of the Colorado Plateau, including Grants uranium region. Subjects include structural boundaries of the Plateau; principal rock units; structural elements of the Plateau, including basins, uplifts, intermediate divisions, monoclines, folds, salt structures, faults, joints, and igneous intrusions; tectonic lineaments of the Plateau; regional mechanics of deformation. Included is a summary of geologic history of the region. Also a discussion on the influence of tectonic activity on distribution and genesis of uranium ore, with discussion of theories of origin of deposits; sources of sediment in host rocks; paleohydrology; hydrothermal activity as a possible source of uranium.

Illustrations: aerial photographs; small-scale structure maps; isopach maps; maps of structural trends and lineaments; diagrammatic sections of monoclines; map of relation of monoclines to Laramide structural trends; map of Laramide stress directions; diagrammatic maps and sections illustrating possible effects of hydrothermal activity in connection with uranium ore-forming processes.

149 Kelley, V. C., 1955c, Tectonics of the Four Corners region: *in* Four Corners Geol. Soc. Guidebook 1st Field Conf., Geology of parts of Paradox, Black Mesa, and San Juan basins, p. 108-117.

Reviews structural geology of a broad region centering at the Four Corners. Emphasizes features beyond Grants uranium region. Treatment includes description of chief tectonic elements; consideration of aspects of genesis of the elements; summary of the tectonic history of the Colorado Plateau region.

Illustrations: small-scale maps of the area; map of tectonic divisions of the Colorado Plateau; combination isopach and structure map of Colorado Plateau and Eastern Rockies; aerial photographs.

150 Kelley, V. C., 1956, Influence of regional structure and tectonic history upon the origin and distribution of uranium on the Colorado Plateau: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 171-178.

Influence of regional structure and tectonic history on the origin and distribution of uranium on the Colorado Plateau, including Grants uranium region. Subjects include regional tectonics; geologic history; paleohydro-dynamic gradients and paleoclimates in relation to genesis of uranium deposits.

Illustrations: small-scale diagrammatic structure maps; diagrammatic structure section; alphabetical index of structural features.

151 Kelley, V. C., 1957, Tectonics of the San Juan basin and surrounding areas: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 44-52.

Comprehensive review of chief structural features around San Juan basin, including Grants uranium region. Subjects include major tectonic elements; regional fracture patterns; origin of San Juan basin.

Illustrations: small-scale diagrammatic structure maps; diagrammatic structure section; alphabetical index of structural elements.

152 Kelley, V. C., 1961, Tectonic map of a part of the upper Rio Grande area, New Mexico: *in* New Mexico Geol. Soc. Guidebook 11th Field Conf., Albuquerque country (in pocket).

Small-scale (approx. 6 miles/inch) tectonic map (base is a net of degrees and minutes of latitude and longitude) of an area centering near Albuquerque. Includes the easternmost part of Grants uranium region. Map modified from "Tectonic map of a part of the upper Rio Grande area, New Mexico" (Kelley, V. C., 1954, U.S. Geol. Survey Map, OM-157).

153 Kelley, V. C., 1963a, Preface: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 1-2.

Introduction to "Geology and technology of the Grants uranium region," published by the New Mexico Bureau Mines Mineral Resources as Memoir 15 in 1963. Subjects include historical background of the publication; history of development of the uranium industry in Grants uranium region.

154 Kelley, V. C., 1963b, Tectonic setting: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 19-20.

Reviews structural geology of Grants uranium region. Subjects include extent and form of the region; chief tectonic elements of the region; local tectonic history, Jurassic to Recent.

Illustrations: small-scale tectonic map of San Juan basin and adjacent areas.

155 Kelley, V. C., 1967, Tectonics of the Zuni-Defiance region, New Mexico and Arizona: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 28-31.

Structural geology of the western part of Grants uranium region, Grants to Gallup and bordering areas to the south, west, and northwest. Describes overall form, boundaries, and chief component structural features of Defiance uplift, Zuni uplift, and Gallup sag, and tectonic history of the area; especially, events of Laramide age and questions pertaining to Laramide deformation. Considers gravity data in recognition and definition of particular structures along which principal Laramide deformation occurred; offsets of lines of regional facies change in determining significance of sinuosity on Defiance Monocline (possibility of right lateral shift at depth).

Illustrations: small-scale tectonic map; 3 insets: Bouget gravity map, isopachous map, and map showing shift of line of facies change across the Defiance monocline.

156 Kelley, V. C., and Clinton, N. J., 1960, Fracture systems and tectonic elements of the Colorado Plateau: University New Mexico Publications in Geology, no. 6, 104 p.; also 1958, U.S. Atomic Energy Comm. RME-108, 107 p.

Studies structure of Colorado Plateau, with descriptions of features of Grants uranium region. Authors use structural divisions to describe Uinta basin, Piceance basin, San Juan

basin, Henry basin, Kaiparowitz basin, Blanding basin, Black Mesa basin, San Rafael swell, Uncompahgre uplift, Circle Cliffs uplift, Monument upwarp, Echo Cliffs uplift, Defiance uplift, Zuni uplift, Archuleta arch, French Mesa and Gallina uplifts, Nacimiento uplift, Puerco fault belt, Lucero uplift, Paradox fold and fault belt, Capitol Reef fold belt, Piute fold belt, Four Corners platform, Red Rock bench, White Canyon slope and Oljeto sag, Kaibito saddle, Preston bench, Cameron bench, Coconino salient, Wapatki bench, Tyende saddle, Chaco slope, Gallup sag, Acoma sag, and Mogollon Slope. The study also considers comparison of fracture systems of the various tectonic elements; regional fracture patterns; origin of the fracture systems.

Illustrations: small-scale (8 miles/inch) colored tectonic map of the Plateau; representation of principal uplifts and their fracture patterns; small-scale map of regional fracture patterns; maps of fracture patterns in local areas; lineament map; photographs.

157 Kelley, V. C., and Wood, G. H., 1946, Lucero uplift, Valencia, Socorro, and Bernalillo Counties, New Mexico: U.S. Geol. Survey Oil and Gas Inv. Map, OM-47.

Geologic map sheet covering the area bordering the easternmost part of Grants uranium region on the south. Includes small-scale tectonic map and geologic map of approximately two 15-minute quadrangles; small-scale structure sections; correlations of stratigraphic sections; written summaries of the stratigraphy, structural geology, and geologic history; evaluation of oil and gas possibilities. Rocks range in age from Precambrian to Quaternary. Structural features include the Comanche thrust belt.

158 Kelley, V. C., and others, 1968, Uranium deposits of the Grants region: *in* New York, Am. Inst. Mining Metall. Petroleum Engineers, v. 1, Ore deposits of the United States, 1933-1967 (Graton-Sales Volume), p. 747-769.

Geology of uranium of Grants uranium region. Subjects include history of discovery, exploration, and mining; local stratigraphy, Todilto and Morrison Formations; local structure; uranium deposits, genesis of deposits. Of these, uranium deposits of the Morrison are especially treated, along with classes of ore bodies (older and younger ores); form of ore bodies; directional orientation of elongate bodies; redistribution of mineralization; forms of small-scale features of mineralization within deposits; distribution of mineralization; carbonaceous material associated with ore; mineral assemblages; genesis of deposits.

Illustrations: small-scale geologic maps and sections; large-scale geologic sections; graphic column showing distribution of mineralization in Morrison Formation.

159 Kerr, P. F., 1958, Uranium emplacement in the Colorado Plateau: Geol. Soc. America Bull., v. 69, p. 1075-1111.

Genesis of uranium deposits of the Colorado Plateau, including Grants uranium region. Contains the examination of the four most plausible hypotheses of origin, hydrothermal, circulatory ground water, ash leach, and syngenetic. Subjects are introduction; interpretation of uranium emplacement; mineral relationships; stratigraphic distribution; structural factors in emplacement; igneous centers; conclusions.

Illustrations: small-scale geologic maps; geologic sketches; photographs; sketches of petrographic relations; schematic diagram; table of stratigraphic distribution of deposits; table of locality; tables of minerals.

160 Kerr, P. F., and Dahl, H. M., 1953, Uranium-fluorite association in the Todilto Limestone, Grants, New Mexico: U.S. Atomic Energy Comm. RME-3051, 6 p.

Laboratory study of Todilto, uranium-fluorite ore from the Ambrosia Lake area, central part of Grants uranium region. Treatment includes description of textures and microstructures; description and identification of mineral elements; consideration of the form, identity, and manner of occurrence of the radioactive substance in the fluorite.

Illustrations: sketches of specimens.

161 Kerr, P. F., and Hamilton, P. K., 1953, Hematite pseudomorphs from the Todilto Limestone, Grants, New Mexico: U.S. Atomic Energy Comm. RME-3068, 9 p.

Laboratory study of some accessory minerals, hematite and associated lepidocrocite, and barite, of Todilto uranium ores of Grants uranium. Genesis of the hematite is thought to bear on genesis of the uranium ore. Topics include identification, features of distribution, paragenesis, and genesis of minerals.

Illustrations: tables of X-ray diffraction data.

162 Kerr, P. F., and Hamilton, P. K., 1954, Quartz crystals from the Todilto

Limestone, Grants, New Mexico: U.S. Atomic Energy Comm. RME-3096, pt. 1, p. 56-59.

Laboratory study of euhedral quartz crystals from Todilto Limestone at Grants, New Mexico, central part of Grants uranium region. Authors remark: "These crystals exhibit the characteristic forms of quartz which has formed below 573°C. Since temperature criteria are meager for the Todilto at this locality, the occurrence of secondary quartz is of interest."

Illustrations: photograph.

163 Kerr, P. F., and Wilcox, J. T., 1963, Structure and volcanism, Grants Ridge area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 205-213.

Study of geology of Grants Ridge area, just north of Grants in the central part of Grants uranium region; includes the F-33 uranium mine, a Todilto deposit. Subjects include local stratigraphy of the section, Chinle Formation through Mancos Shale inclusive, of Triassic to Cretaceous age; alteration of Bluff and Summerville formations; local structural elements such as San Rafael fault; landslides which are numerous basalt-capped blocks that have been displaced downward; volcanic rocks and structures of the area; origin of alteration of shale of Summerville Formation in proximity to Todilto uranium deposits; origin of the landslide blocks; location of source vents of the volcanic sequence; control of flow of basalt by Quaternary stream valleys; origin of the varied rock types in the felsic part of the volcanic sequence; control of mafic phase of igneous activity by San Rafael fault; age of mineralization of Todilto deposits with respect to age of volcanism.

Illustrations: small-scale geologic map; large-scale geologic sections; aerial photographs; sketches.

164 Keys, W. S., and Dodd, P. H., 1958, Lithofacies of continental sedimentary rocks related to significant uranium deposits in the western United States: United Nations Internat. Conf. Peaceful Uses Atomic Energy, 2nd Proc., Geneva, v. 2, p. 367-378.

Reviews sedimentary features of host-rock formations in the western United States and features of distribution of uranium in the rocks. Deposits at Ambrosia Lake are mentioned.

Illustrations: table of characteristics of significant uranium districts in continental sedimentary rocks; small-scale map of lithofacies in part of Colorado Plateau.

165 King, V. L., 1952, Hospah oil field McKinley County, New Mexico: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geological symposium of the Four Corners region, p. 95-97.

Hospah oil field, in area bordering north central part of Grants uranium region. Subjects include local structural geology and stratigraphy; Hospah anticline and faults; Hospah Sandstone (Cretaceous).

Illustrations: small-scale structure-contour map.

166 King, V. L., and Wengerd, S. A., 1957, The Hospah oil field, McKinley County, New Mexico: *in* Four Corners Geol. Soc. Guidebook 1st Field Conf., Geology of southwestern San Juan basin, p. 155-168.

Studies geology of Hospah oil field, north of and adjacent to northern boundary of the central part of Grants uranium region. Subjects include history of oil exploration in the area; history of development of the field; oil production; regional stratigraphy and structural geology; structure of Hospah anticline; local stratigraphy of Hospah Sandstone; trapping mechanism of Hospah oil; origin of Hospah field.

Illustrations: Maps; sections; tables of data.

167 Kirkland, D. W., and Anderson, R. Y., 1970, Microfolding in the Castile and Todilto evaporites, Texas and New Mexico: Geol. Soc. America Bull., v. 81, p. 3259-3281.

Study of microfolds in Castile and Todilto Formations. The Castile is a Permian formation of Eddy County, New Mexico, and Culberson County, Texas; the Todilto is a Jurassic formation of Grants uranium region. Microfolds in the Castile are in a sequence of interlaminated anhydrite and calcite; folds in the Todilto are in the limestone member. Subjects include microfolds in Castile Formation, occurrence and description; microfolds in Todilto Limestone, occurrence and description; Genesis of microfolds considered, as well as previous hypotheses and tectonic origin, Castile and Todilto microfolds.

Illustrations: large-scale maps; photographs; photomicrographs; sketches; rose diagrams; graphic representations of characteristics of deformation.

168 Kittle, D.F., 1963, Geology of the Jackpile mine area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 167-176.

Geology and uranium deposits of "Jackpile Sandstone" (a division of the Morrison) of Laguna district, eastern part of Grants uranium region. Treatment emphasizes Jackpile and Paguate deposits. Subjects include local stratigraphy, local structural elements; influence of Jurassic flexures on "Jackpile" sedimentation; form of deposits; distribution of mineralization with respect to stratigraphic position in the "Jackpile"; distribution of mineralization with respect to structural elements; ore controls; mineral assemblages; genesis of deposits.

Illustrations: small-scale isopach and structure-contour maps; large-scale geologic section; columnar section; photograph of Jackpile mine.

169 Kittle, D. F., and others, 1967, Uranium deposits of the Grants region: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 173-183.

Editor's note: "This contribution to the Guidebook was written in 1966 for publication in the forthcoming Graton-Sales Volume, which will be published early in 1968 by the American Institute of Mining, Metallurgical and Petroleum Engineers as a sequel to the well known classic *Ore Deposits of the Western States*, published by AIME in 1933. Coauthor Kittle has condensed and updated the article for publication at this time."

170 Knox, J. A., and Gruner, J. W., 1957, Mineralogy of the Ambrosia Lake uranium deposits in McKinley County, New Mexico: *in* U.S. Atomic Energy Comm. RME-3148, pt. 1, Annual report for April 1, 1956 to March 31, 1957, p. 5-28.

Geologic study of Rio de Oro deposit (Stella Dysart shaft) especially, Morrison mineralization, Ambrosia Lake trend, central part of Grants uranium region. Subjects include lithology of host rock; distribution of ore; alteration of host rock; grade of ore; mineral assemblage; paragenesis of the various elements in the deposit; genesis of the deposit.

171 Konigsmark, T. A., 1955, Color changes and uranium deposits of the upper Morrison Formation northeast flank of the Zuni uplift, New Mexico: U.S. Atomic Energy Comm. RME-76, pt. 1, 15 p.

Distribution of uranium mineralization, especially Morrison, with respect to geologic features in the western part of Grants uranium region, Grants west to Gallup. Subjects include upper Morrison stratigraphy; regional structure; distribution of mineralization; types of occurrence of favorably colored strata; ore controls; genesis of deposits.

Illustrations: small-scale geologic map; graphic column showing stratigraphic location of deposits; geologic sections showing types of occurrence of favorably colored strata.

172 Konigsmark, T. A., 1958, Uranium deposits in the Morrison Formation on the northeast flank of the Zuni uplift exclusive of Ambrosia Lake, New Mexico: U.S. Atomic Energy Comm. RME-115, 34 p.

Study of geology and Morrison uranium deposits of the western part of Grants uranium region, Grants west to Gallup exclusive of Ambrosia Lake trend, and petrographic investigations. Subjects include stratigraphy (Morrison especially), facies, occurrence of red sandstone, and depositional environments; structural geology; geology of specific ore deposits, Foutz no. 1 and no. 2, Alta, Evelyn, Francis, Poison Canyon, Mesa Top, and Blue Peak; features of occurrence of deposits; genesis of deposits.

Illustrations: small- and large-scale geologic maps; small- and large-scale geologic sections; stratigraphic (columnar) section; histograms, portrayal of dip direction of crossbedding; table giving mineral composition of Morrison sandstone.

173 Laughlin, A. W., and others, 1972, Late Cenozoic basalts from the Bandera lava field, Valencia County, New Mexico: Geol. Soc. America Bull., v. 83, p. 1543-1552.

Petrologic study of young volcanics, including McCarty flow of Grants area (central part of Grants uranium region and areas south). Subjects include geologic setting of the volcanics; volcanic activity; analysis of rocks; genesis of rocks.

Illustrations: index maps; tables and diagrams representing analyses.

174 Laverty, R. A., 1967, Geomorphology and structure in the Grants mineral belt:

in New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 188-194.

Studies structural elements, especially fractures, of southern San Juan basin, emphasizing forms of Grants uranium region, and studies geomorphic expression of features on small-scale aerial photographs. Subjects include definition and distribution of fracture patterns; alignment of fractures relative to uplifts and San Juan basin; boundaries and age of San Juan basin; occurrence of uranium ore in relation to fractures; significance of fractures as a control of Morrison host rock sedimentation; importance of fractures as a control of circulation of solutions influencing uranium distribution.

Illustrations: aerial photographs.

175 Laverty, R. A., and Gross, E. B., 1956, Paragenetic studies of uranium deposits of the Colorado Plateau: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 195-201.

Mineralogy and paragenesis of several primary uranium deposits of the Plateau region, including Todilto deposits of Grants uranium region and summarization of similarities of deposits: host rock, apparent precipitants, manner of textural occurrence of ore minerals, and chemical environment of site of ore deposition. Subjects are genesis of deposits, age of mineralization; distribution of mineralization with respect to Todilto stratigraphy and structural features; classification of Todilto ores (fluoritic and nonfluoritic); paragenesis; principal precipitant of the ore material.

Illustrations: photomicrographs from thin and polished sections; chart showing paragenetic sequences of deposits.

176 Laverty, R. A., and others, 1963, Ore processes: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 191-204.

Subjects pertaining to genesis of uranium deposits of Grants uranium region are source of ore elements; migration of mineralizing solutions; precipitation of ore elements; enrichment of ore from leaching and erosion, as a condition influencing location of deposits; protection of deposits. Treatment discusses source of ore elements and considers geology of region in connection with principal theories; hydrothermal, ash leach, granite leach, and syngenetic. Authors consider possible routes of movement of migration of mineralizing solutions and identity, source, emplacement and reaction of precipitation in treatment of precipitation of ore elements. Authors also consider source of enriching uranium and the mechanism of its emplacement, as well as conditions necessary for formation and preservation of deposits: protection of the precipitant until introduction of uranium and protection of the precipitated uranium until mining.

Illustrations: small-scale geologic map of Grants uranium region and adjacent areas.

177 Leopold, L. B., 1943, Climatic character of the interval between the Jurassic and Cretaceous in New Mexico and Arizona: Jour. Geology, v. 51, p. 56-62.

Study of the contact (unconformable) between the "Morrison" of Jurassic age and the Dakota of Cretaceous age in New Mexico and Arizona; includes Grants uranium region. Subjects are distribution of kaolin and kaolinized rock at the contact and origin of the kaolin.

Illustrations: photographs; table of chemical analysis of kaolin; table of measured stratigraphic sections.

178 Leopold, L. B., and Snyder, C. T., 1951, Alluvial fills near Gallup, New Mexico: U.S. Geol. Survey Water-Supply Paper 1110-A, 19 p.

Stratigraphic study of Recent alluvium near Gallup, New Mexico, westernmost part of Grants uranium region. Subjects include stratigraphic divisions of the section and definition of new formations, Gamerco (lowest), Nakaibito (middle), unnamed sequence overlying the Nakaibito, and modern part of the section; contacts, lithologies, thickness, and distribution of units; correlation of the Gallup units with divisions of sections established by others; correlation of Gallup units with local archaeological ages; dating of units in years; Recent geologic history. Authors conclude deposition of Nakaibito Formation was in progress during Pueblo 2 age as late as A.D. 1200 and suggest that modern degradation began about 1860, possibly brought about through postsettlement grazing.

Illustrations: large-scale geologic map; geologic sections; photographs; measured stratigraphic sections.

179 Linton, W. A., 1963, Uranium logging techniques: *in* New Mexico Bureau

Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 222-233.

Describes logging techniques applied in uranium work in Grants uranium region. Subjects include borehole measurements; instrumentation; gamma-ray calibration; gamma-ray log interpretation; hole deviation.

Illustrations: photographs; reproductions of typical logs of drill-holes; figure illustrating variation of gamma-ray response to beds of equal grade of U_3O_8 and unequal thickness; graphs utilized in conversion of observed gamma-ray intensity (cps) to percent U_3O_8; comparison of definitions of bed thickness by Geiger and scintillation detectors; graphic representations of drift surveys.

180 Lipman, P. W., and Moench, R. H., 1972, Basalts of the Mount Taylor volcanic field, New Mexico: Geol. Soc. America Bull., v. 83, p. 1335-1343.

Petrologic study of volcanic rocks of Mount Taylor field, in the central and eastern parts of Grants uranium region. Subjects include geologic setting of the field; gross aspects of the volcanic assemblage; petrology and genesis of basalts. Authors conclude that the sequence of Mt. Taylor field is compatible with a model of partial melting or last fractionation of magma at progressively shallower levels in the upper mantle and suggest that bounding discontinuities between structural provinces may extend through the sialic crust to influence magma generation at upper mantle depths.

Illustrations: generalized geologic map; table of analyses; figure showing variations in composition of basalts.

181 Lochman-Balk, Christina, 1959, List of stratigraphic names used in northwest and central New Mexico: *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 100-111.

Names formations and related units of Grants uranium region and adjacent regions and summarizes stratigraphic information for each unit. Subjects are areal distribution, as originally described; reference in which unit was first defined or mentioned; type locality; short lithologic description (includes thickness) of unit at type locality or in type area; age to stage; contacts; emending or refining descriptions; additional stratigraphic information for units in area of field conference.

182 Lochman-Balk, Christina, 1967, Lexicon of stratigraphic names used in northwest New Mexico and adjacent states: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 15-27.

Formations and related units recognized in northwest New Mexico and adjacent states (including Grants uranium region) and summary of stratigraphic information for each division. Subjects include: areal distribution; reference in which unit was first defined or mentioned; type locality; short lithologic description (includes thickness) at type locality or in type area; age to stage; contacts; emending or refining descriptions of note; additional information on areal distribution, thickness, and lithology in the area of the field conference.

Illustrations: correlation of stratigraphic nomenclature of the region.

183 Lovering, T. G., 1956, Radioactive deposits in New Mexico: U.S. Geol. Survey Bull. 1009-L, 390 p.

Summary of information available on uranium deposits and mining activity in New Mexico before 1952 (footnote indicates some later information added). Mention is made of uranium mineralization in Grants uranium region, said to occur in Todilto Limestone and overlying basal Summerville Formation and in Westwater Canyon and Brushy Basin members of Morrison Formation and overlying Dakota Sandstone. Includes description of geology of the area and specific claims and properties.

Illustrations: large- and small-scale geologic maps of deposits in Grant County; small-scale geologic map of La Ventana Mesa area; sketch maps; representations of assay data; graphic sections; tables of analyses; table of uranium minerals; table summarizing significant features of radioactive deposits in New Mexico.

184 MacRae, M. E., 1963, Geology of the Black Jack No. 1 mine, Smith Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 45-48.

Geology and uranium deposits (upper Westwater) of Black Jack No. 1 mine, Smith Lake area, western part of Grants uranium region including "prefault" and "postfault" ore. Subjects include stratigraphy and structural geology; form of deposit; distribution of mineralization with respect to stratigraphy, sedimentary particulars, structural elements, and

coloration of sediments; mineral assemblage; classification of ore in deposit as "prefault" and "postfault"; controls of deposition of ore; redistribution of ore; faults as channels controlling migration of "postfault" ore solutions.

Illustrations: large-scale plan map of the mine; tables of chemical analyses of samples of ore and barren rock.

185 Marvin, R. G., 1967, Dakota Sandstone-Tres Hermanos relationship southern San Juan basin area: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region: p. 170-172.

Stratigraphic study of lower part of the Cretaceous section in Grants uranium region. Subjects are review of problems of nomenclature and correlation of parts of the Dakota-Mancos section; consideration of correlation of units in drill-hole sections between Grants (eastern end of line of section) and Defiance monocline (west of Gallup and the western end of line of section). Correlation of units is in context with the condition of westward onlapping of the Cretaceous shoreline and consequent wedging-out of units and changes in facies.

Illustrations: correlation of electric logs between Grants and Defiance monocline.

186 Mathewson, D. E., 1953, Reconnaissance of the Morrison Formation north of Bluewater, McKinley County, New Mexico: U.S. Atomic Energy Comm. RME-57, 15 p.

Describes field studies of the Morrison in central part of Grants uranium region, around Ambrosia Lake. Subjects include structural geology, stratigraphy; relative amount of limonite in sections as a guide to ore.

Illustrations: measured sections; map showing structural features, stratigraphy (including sedimentary trends), and varying proportions of limonite.

187 Matthews, D. C., 1963, Rudiments of uranium ore metallurgy: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 268-269.

Describes processing of uranium ores of Grants uranium region. Subjects include ore grinding and leaching; solids-fluid separation; solution extraction; eluting, stripping, and/or rejuvenating; precipitation; special heat treating; economic aspects of milling.

188 McCann, F. T., 1938, Ancient erosion surface in the Gallup-Zuni area, New Mexico: Am. Jour. Sci., 5th ser., v. 36, p. 260-278.

Stratigraphic study of young deposits of areas bordering the westernmost part of Grants uranium region. Relations ordinarily reflect significant events of late Cenozoic history of uranium areas; considers uplift of Zuni Mountains in relatively recent time. Subjects are stratigraphy and structure of the pre-Tertiary rocks; the Tertiary deposits; the Pleistocene (?) deposits; Zuni erosion surface; age of the erosion surface; Tertiary and early (?) Pleistocene history; correlation of Zuni erosion surface with neighboring surfaces.

Illustrations: generalized geologic map; contour map of Zuni erosion surface; photographs.

189 McKee, E. D., 1951, Sedimentary basins of Arizona and adjoining areas: Geol. Soc. America Bull., v. 62, p. 481-505.

Studies distribution and thickness of sedimentary deposits in Arizona and adjoining areas to assemble existing knowledge regarding times and places of sedimentation and relative rates of deposition within this region (extends into New Mexico and includes Grants uranium region). Subjects include Precambrian basins of deposition; Lower Paleozoic deposits; Pennsylvanian-Permian deposits; Triassic-Jurassic deposits; Lower Cretaceous deposits; Upper Cretaceous deposits; total deposits of Paleozoic time and of combined Paleozoic and Mesozoic time; Cenozoic deposits.

Illustrations: isopach maps; map of the position of Uncompahgre-San Luis Highland; map of axes of Paleozoic geanticlines in Cordilleran geosyncline; map showing location and thickness of Cenozoic deposits in principal basins of Arizona.

190 McKee, E. D., and McKee, E. H., 1972, Pliocene uplift of the Grand Canyon region—time of drainage adjustment: Geol. Soc. America Bull., v. 83, p. 1923-1931.

Stratigraphic study connected with dating the late Tertiary uplift of the southern part of the Colorado Plateau, including Grants uranium region. Relations are west of the region in northern Arizona. Uplift of the southern part of the Colorado Plateau occurred within 5 to 10 m.y. B.P. or in early to middle Pliocene time, which was also the time of cutting of Grand Canyon within the Plateau province. Subjects include surface underlying "ancestral gravel

deposits" and the deposits themselves; basalt flows overlying the gravel deposits; events subsequent to covering of "ancestral gravels."

Illustrations: photographs; table showing composition and texture of "ancestral gravels"; stratigraphic table; table of analytical data pertaining to K-Ar age determinations.

191 McKee, E. D., and others, 1956, Paleotectonic maps of the Jurassic System: U.S. Geol. Survey Misc. Geol. Inv. Map I-175.

Reviews—in map folio form—of Jurassic stratigraphy and geologic history of the United States, chiefly by region. ("Southwest Region" gives most of the data pertaining to Grants uranium region.) Subjects include the lower boundary of the system and rocks directly beneath; thicknesses of Jurassic rocks in various regions; lithofacies of the section; depositional environments and paleogeography.

Illustrations: geologic map plates of geologic units directly beneath Jurassic System; summary of Jurassic rock thicknesses; lithofacies and thickness; paleogeographic maps of the United States during the Jurassic Period; environments of deposition of Jurassic sediments for selected times and places, including northwestern New Mexico. (Some plates have geologic sections and stratigraphic correlations.)

192 McKee, E. D., and others (eds.), 1967, Evolution of the Colorado River in Arizona—an hypothesis developed at the Symposium on Cenozoic Geology of the Colorado Plateau in Arizona, August 1964: Mus. Northern Arizona Bull. 44, 68 p.

Symposium on the history of Colorado River in Arizona. Information is presented as a series of sketches of stratigraphy and geologic history; a summary of the events listed for individual areas; discussion of the evolution of Colorado River in Arizona. "Eastern Navajo Reservation area" borders Grants uranium region on west. A hypothesis of evolution of Colorado River in northern Arizona states that establishment of the modern Colorado River drainage pattern began sometime in the Pliocene between 2.6 and 10.6 m.y. ago. Attention also directed problematic circumstance that in approximately the last million years, Colorado River has downcut thousands of feet. Authors suggest: "The major factor contributing to initial rapid downcutting probably was epeirogenic uplift of the region—an event generally recognized for southwestern United States during late Cenozoic time."

Illustrations: maps of individual areas; stratigraphic chart correlating stratigraphy and events of the area; diagrammatic maps and block diagrams illustrating development of drainage.

193 McKee, E. H., and Anderson, C. A., 1971, Ages of basalt flows in north-central Arizona and their relationship to the Colorado Plateau Province (abs.): Geol. Soc. America Abstracts with Programs, v. 3, p. 159.

Information (from north-central Arizona) leading authors to suggest that some time between 8 and 10 m.y. ago "prevailing drainage changed from northward to southward, marking the beginning of the uplift along the southern part of the Colorado Plateaus."

194 McKelvey, V. E., 1955, Search for uranium in the United States: U.S. Geol. Survey Bull. 1030-A, 64 p.

Reviews distribution of concentrations of uranium in the United States, including mineralization of Todilto Limestone and Morrison Formation of Grants uranium region. Subjects include types of uranium deposits; distribution of uranium; methods of prospecting; function of carbonaceous matter associated with uranium; effect of migration of uranium from primary concentrations; source of uranium in deposits in continental sandstones.

Illustrations: small-scale maps showing the location of deposits.

195 McKelvey, V. E., and others, 1955, Origin of uranium deposits: *in* The Economic Geology Publishing Co., Fiftieth anniversary volume, 1905-1955, Urbana, Ill., p. 464-533.

Summarizes information available on the origin of uranium deposits to define critical problems and to indicate some economic applications of the data in certain fields. Considerations include deposits of the Colorado Plateau and Grants uranium region. Subjects include: geochemistry of uranium; occurrence of uraniferous deposits; uraniferous igneous rocks; uranium in vein deposits; sandstone-type deposits; uraniferous coal and associated carbonaceous shale, mode of occurrence and origin; uraniferous marine sedimentary rocks.

Illustrations: tables of information; representations of significant chemical relations; schematic representation of major aspects of the geochemical cycle of uranium.

196 McKelvey, V. E., and others, 1956, Summary of hypothesis of genesis of

uranium deposits: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to geology of uranium and thorium, p. 41-53.

Reviews distribution of uranium and explanations for its presence in concentrations. Subjects include the relation of distribution of uranium in igneous rocks and veins to chemistry of uranium; bearing of the chemistry of thorium on its distribution in igneous rocks relative to uranium; uranium deposits in sandstone; uraniferous coal and associated carbonaceous shale; uraniferous black shale; uraniferous marine phosphorites.

197 McLaughlin, E. D., Jr., 1963, Uranium deposits in the Todilto Limestone of the Grants district: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 136-149.

Reviews geology of Todilto Limestone and Todilto uranium deposits of Ambrosia Lake area, central part of Grants uranium region. Subjects include local stratigraphy of the Todilto; recrystallization of limestone, diagenetic and structural; Todilto structural features, joint patterns, and folds; distribution of mineralization; ore deposits; mineral assemblages; geologic guides to Todilto ore depostis; genesis of Todilto structural features; relations of mineralization to structural features and recrystallization of limestone; genesis of uranium deposits.

Illustrations: small-scale map showing distribution of deposits; correlation of electric log signatures with Todilto stratigraphy; large-scale plan and wall maps of the Faith mine; diagrammatic section illustrating varieties of Todilto folds; photographs of Todilto structural features.

198 Megrue, G. H., and Kerr, P. F., 1965, Alteration of sandstone pipes, Laguna, New Mexico: Geol. Soc. America Bull., v. 76, p. 1347-1360.

Focuses on origin of "sandstone pipes" in the Laguna district, eastern part of Grants uranium region. Authors conclude that the pipes are "solution collapse" features and approach origin through investigation of effects of alteration of sedimentary rocks within the pipes to determine character of the altering fluids. They conclude that the pipes may have formed through stoping by hydrothermal solutions in post-Cretaceous time. Subjects include geologic setting; stratigraphic extent of pipes; pipe structure; gross aspects of lithology of rocks within pipes; laboratory investigations of texture, composition, and alteration of rock. Occurrence of uranium ore in some pipes implies that this uranium may also be of hydrothermal origin.

Illustrations: small-scale geologic map showing distribution of pipes in Laguna area; stratigraphic table; sketches; photographs; tables of analyses.

199 Megrue, G. H., and Kerr, P. F., 1968, Alteration of sandstone pipes, Laguna, New Mexico–reply; Geol. Soc. America Bull., v. 79, p. 791-794.

Replies to discussion of Moench and Hilpert (1968) of genesis of sandstone pipes in Laguna district (eastern part of Grants uranium region), part of debate on the question of importance of pipes to uranium exploration. Authors hold that the pipes are probably of hydrothermal origin and that "the extent to which uranium ions were carried by these solutions remains to be established." Subjects include distribution of uranium mineralization with respect to pipe structures; age of pipe formation; mechanism of pipe formation.

200 Melancon, P. E., 1963, History of exploration: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 3-5.

Reviews history of uranium exploration in Grants uranium region. Subjects include early discoveries; methods of exploration; exploration in Todilto Limestone; exploration in Morrison Formation; exploration in Dakota Sandstone.

201 Miller, D. S., and Kulp, J. L., 1963, Isotopic evidence on the origin of the Colorado Plateau uranium ores: Geol. Soc. America Bull., v. 74, p. 609-630.

Comprehensive study of isotopic data about the origin of Colorado Plateau uranium ores. Morrison and Todilto ores of Ambrosia Lake district mentioned specifically. Subjects include previous efforts to date uranium mineralization by isotopic methods; development of techniques of analysis; isotopic geochemistry; experimental procedures and results; calculations of isotopic ages; isotopic data obtained for the various uranium districts; implications of isotopic data for the origin of the Colorado Plateau ore, interpretation of isotopic data; temperature (low) of depositional environment of uranium; synthesis of geologic, geochemical, and isotopic data with regard to origin of Plateau uranium deposits.

Illustrations: tables of data and isotopic analyses; tables listing isotopic ages of various ores; histogram of U^{235}/Pb^{207} ages obtained from primary uranium minerals of the Plateau.

202 Mirsky, Arthur, 1953, Preliminary report on uranium mineralization in the Dakota sandstone, Zuni uplift, New Mexico: U.S. Atomic Energy Comm. RME-47, 21 p.

Field study of uranium mineralization in the Dakota of the western part of Grants uranium region, Grants west to Gallup. Considers relation of uranium mineralization to stratigraphic particulars. Subjects include stratigraphy of the lower Dakota, especially paleostream channels; uranium mineralogy, distribution of mineralization with respect to lithology, stratigraphy of the Dakota, paleostream channels, carbonaceous material, joints, and coloration of rock in 6 mines; depositional environment of the lower Dakota.

Illustrations: small-scale generalized geologic maps; large-scale plan map of one mine, showing directional orientation of mineralization with respect to crossbedding and joints; chart showing stratigraphy of the section, Morrison-lower Dakota inclusive; measured section of lower Dakota; large-scale geologic sections of lower Dakota; sketches showing details of distribution of mineralization.

203 Moench, R. H., 1962a, Properties and paragenesis of coffinite from the Woodrow mine, New Mexico: Am. Mineralogist, v. 47, p. 26-33.

Study of coffinite of Woodrow deposit in Laguna district, eastern part of Grants uranium region. Discovery of well-crystallized coffinite in small specimen made study possible; usually coffinite in Laguna district is so finely divided and so intimately mixed with carbonaceous material that it has been detected by X-ray methods only. Its paragenetic relations to the material, vanadium-bearing minerals, and sulfide minerals have remained largely unknown. Subjects include habit of the coffinite (the well-crystallized specimen); its properties in reflected and transmitted light; its paragenetic relations to associated minerals in the specimen and in the Woodrow deposit as a whole; geology of the Woodrow Pipe; ore mineralogy; well-crystallized coffinite; paragenesis.

Illustrations: photomicrographs.

204 Moench, R. H., 1962b, Vanadium-rich garnet from Laguna, New Mexico: *in* U.S. Geol. Survey Prof. Paper 450-B, Short papers, p. 67-69.

Preliminary data establishing existence of the vanadium-rich garnet and describing its occurrence and geologic significance. Occurs in Sandy mine in Laguna area, eastern part of Grants uranium region, a uranium-vanadium deposit at the top of Entrada Formation and extending upward into Todilto Limestone. The strata and deposit at the mineral locality are cut by a diabase sill that metamorphosed rocks and the deposit for a few feet from the contact. The vanadium-rich garnet is a product of the metamorphism. Subjects include distribution of uranium mineralization in Laguna area; sills and dikes of the area; mineral assemblage of Sandy mine deposit and other Entrada-Todilto deposits; textural relations of vanadium clay in Sandy mine class deposits; distribution of vanadium clay of deposits with respect to structural features and laminations of Todilto Limestone; attitude of strata in Sandy mine; dikes and sills in the mine area and their metamorphic effects; garnets of the metamorphic mineral assemblage and particulars of distribution; geologic occurrence of the vanadium-rich garnet; chemical composition, outward form, and textural relations of the garnet; association of the garnet with vanadium clay. Diabase sills and dikes of the area have been inferred to be younger than the uranium-vanadium deposits from structural evidence and presence of the garnet further substantiates this age relation.

Illustrations: large-scale geologic map and section of Sandy mine; chart of quantitative and semiquantitative spectrographic analyses of vanadium-rich garnet.

205 Moench, R. H., 1963a, Geologic map of the Seboyeta quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-207.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

206 Moench, R. H., 1963b, Geologic map of the Laguna quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-208.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

207 Moench, R. H., 1963c, Geologic limitations on the age of uranium deposits in the Laguna district: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 157-166.

Reviews geologic evidence of the age of mineralization around Laguna (eastern part of Grants uranium region) and studies genesis of deposits. Deposits are in Entrada, Todilto, and Morrison Formations. Subjects include local stratigraphy of the section, Chinle-Mesaverde,

inclusive; igneous rocks; structural setting and tectonic history; distribution of mineralization in the region as a whole; form and dimensions of deposits in the "Jackpile Sandstone" (division of Morrison Formation); distribution of mineralization in the "Jackpile" with respect to sedimentary particulars; ore assemblage of deposits in the "Jackpile"; relation of deposits to geologic structures; and age of mineralization, depth of formation, nature of transporting solutions, source of ore elements, and precipitation mechanisms of deposits.

Illustrations: small-scale geologic map; fence diagram; field sketches; photographs.

208 Moench, R. H., 1964a, Geology of the Dough Mountain quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-354.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

209 Moench, R. H., 1964b, Geology of the South Butte quadrangle, New Mexico—Valencia County: U.S. Geol. Survey Geol. Quad. Map GQ-355.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

210 Moench, R. H., and Hilpert, L. S., 1968, Alteration of sandstone pipes, Laguna, New Mexico—discussion: Geol. Soc. America Bull., v. 79, p. 787-790.

Megrue and Kerr (1965) discussing genesis of sandstone pipes of Laguna district (eastern part of Grants uranium region), part of debate on importance of pipes to uranium exploration. Authors hold that pipes formed through the process of foundering of sand into spring vents during compaction and expulsion of water; that pipes could not have served as conduits for ascending hydrothermal solutions; and that occurrence of uranium deposits in some pipes indicates only that pipes were locally favorable for uranium deposition. Subjects include age of pipes; vertical continuity of pipes; origin of pipes.

211 Moench, R. H., and Meyrowitz, Robert, 1964, Goldmanite, a vanadium garnet from Laguna, New Mexico: Am. Mineralogist, v. 49, p. 644-655.

Formal naming and description of the vanadium-rich garnet from the "Sandy mine area," treated in Moench, 1962b. The "Sandy mine" is an area of Entrada-Todilto uranium mineralization of Laguna district, eastern part of Grants uranium region. Subjects include occurrence; separation; properties; composition; analytical procedures; formula; discussion; the name Goldmanite.

Illustrations: large-scale geologic map and sections; tables of analyses.

212 Moench, R. H., and Puffett, W. P., 1963a, Geologic map of the Arch Mesa quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-211.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

213 Moench, R. H., and Puffett, W. P., 1963b, Geologic map of the Mesa Gigante quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-212.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

214 Moench, R. H., and Schlee, J. S., 1967, Geology and uranium deposits of the Laguna district, New Mexico: U.S. Geol. Survey Prof. Paper 519, 117 p.

Comprehensive study of geology and uranium deposits of Laguna district, eastern part of Grants uranium region. Stratigraphy includes divisions of the section, Chinle Formation-Mesaverde Group, origin of the formations, and stratigraphy of surficial deposits. Igneous rocks include age of rocks, petrography, metamorphic effects, and mode of intrusion of diabase dikes and sills, a monchiquite dike, eruptive rocks of Mount Taylor, basalt flows, and volcanic necks and cones. Structure includes Jurassic structural elements and Cenozoic structural elements. Geomorphology includes the Ortiz surface and geomorphic history. Geology of uranium deposits includes Southern San Juan basin mineral belt, contrasting host-rock characteristics, composition of ores, ore textures, sulfur isotopes, description of deposits, age of deposits, origin of deposits, and resources in unexplored ground. Southern San Juan basin mineral belt includes description of Grants uranium region as a mineralized district (the two terms are synonymous). Contrasting host-rock characteristics include particulars of stratigraphy, lithology, and transmissivity of various host rocks. Composition of ores includes host-rock mineralogy, minerals of unoxidized uranium deposits, oxidation products, uranium and vanadium content, minor elements, and carbonaceous matter and fossil wood. Ore textures are descriptions of textural relations and paragenesis of principal components of ores of deposits of the area. Sulfur isotopes include characteristics of the isotopic composition of sulfur in minerals associated with the ores. Description of uranium deposits includes the Jackpile, Saint Anthony, Windwhip, Woodrow, Chavez, Sandy and Crackpot mines, and various unnamed deposits. Genesis of deposits includes age of mineralization, source of ore elements, migration of mineralizing solutions, chemical

characteristics of transporting medium, and precipitation of ore elements. Resources in unexplored ground includes favorability of areas beyond presently defined limits of region.

Illustrations: fence, stratigraphic, orientation, stereogram, and distribution diagrams; small- and large-scale geologic maps; geologic sections; photographs; photomicrographs; sketches; infrared spectrograms; tables of stratigraphy, element distribution, and analyses.

215 Moench, R. H., and others, 1965, Geologic map of the La Gotera quadrangle, Sandoval and Valencia Counties, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-371.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

216 Momper, J. A., 1957, Pre-Morrison stratigraphy of the southern and western San Juan basin: Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 85-94.

Summary of stratigraphy, stressing Paleozoic and Triassic rocks, of the area around the southern part of San Juan basin, including Grants uranium region. Subjects include Precambrian rocks; chief hiatuses of the section; Cambrian-Devonian rocks; Mississippian rocks; Pennsylvanian rocks; Permian rocks; Triassic rocks; Jurassic rocks.

Illustrations: small-scale geologic map; isopach map of lower Triassic Moenkopi Formation; stratigraphic section of relations in southern part of San Juan basin; chart of stratigraphic nomenclature; table of oil well data.

217 Momper, J. A., and Tyrrell, W. W., Jr., 1957, Catalog of stratigraphic names of the southwest San Juan basin and adjacent areas: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 17-24.

Lexicon of rock and time-rock units of San Juan and McKinley Counties and nearby areas (region includes Grants uranium region). Description of stratigraphic divisions includes a real distribution; first reference in literature; type locality; lithology and thickness; origin of units.

218 Nash, J. T., 1968, Uranium deposits in the Jackpile Sandstone, New Mexico: Econ. Geology, v. 63, p. 737-750.

Studies uranium mineralization in Jackpile Sandstone of Laguna district, eastern part of Grants uranium region. Subjects include petrology of the host sandstone; relation of ore deposits to sedimentary features; ore minerals; sedimentary controls of ore distribution; relative permeability of rocks and water-table conditions; paragenesis of minerals; alteration of sediments; genesis of deposits.

Illustrations: columnar section of the local stratigraphy; tables and diagrams showing composition of sediments; photomicrographs.

219 Nash, J. T., and Kerr, P. F., 1966, Geologic limitations on the age of uranium deposits in the Jackpile Sandstone, New Mexico: Econ. Geology, v. 61, p. 1283-1287.

Studies newly discovered small pocket of uranium ore at top of Jackpile Sandstone, uppermost division of Morrison Formation in Laguna district, eastern part of Grants uranium region. Investigation emphasizes relation of the pocket and the overlying Dakota Formation as direct evidence of the age of mineralization. Subjects include the form, dimensions, constitution, and detailed stratigraphic relations of the pocket of ore; local lithology of Jackpile Sandstone; lithology and stratigraphy of overlying Dakota sediments; favorability of closely overlying black shale of the Dakota for mineralization, as evidence of a pre-Dakota age; depth of emplacement of ore in pocket; history of ore in pocket; age of Jackpile ore. Implication of significant differences in the absolute age of Todilto and Jackpile ores considered and conclusions about multiple periods of ore deposition in the Grants-Laguna area are drawn.

Illustrations: longitudinal and cross sectional sketches of the ore pocket; table showing composition of sediments.

220 Newman, W. L., 1962, Distribution of elements in sedimentary rocks of the Colorado Plateau—a preliminary report: U.S. Geol. Survey Bull. 1107-F, p. 337-445.

Distribution of elements in sedimentary rocks of the Colorado Plateau, including Grants uranium region. Studies physical and chemical features of the sedimentary rocks of the Colorado Plateau. Subjects include sedimentary rocks of the Precambrian, Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, and Permian; sedimentary rocks of the

Triassic Moenkopi, Chinle, and Wingate formations; sedimentary rocks of the Jurassic Kayenta, Navajo, Carmel, Entrada, Curtis, Todilto, Summerville, Cow Springs, Bluff, and Morrison (Salt Wash, Recapture, Westwater Canyon, and Brushy Basin members) formations; sedimentary rocks of the Lower Cretaceous, Upper Cretaceous, and Tertiary. Subjects of chemical features in sedimentary rocks include distribution of elements in basal sandstones of the Chinle; stratigraphic distribution of elements in sandstones of pre-Tertiary age; distribution of elements in mudstone of various geologic ages; distribution of elements in limestone; distribution of selenium; distribution of uranium deposits with respect to characteristics of distribution of elements; source of uranium and vanadium in deposits.

Illustrations: maps showing aerial distribution of formations; maps showing distribution of elements in formations; tables of analyses; tables showing original volumes of classes of sediment in chief formations; table of mineral components of sandstone of the Salt Wash.

221 (*This entry deleted*)

222 Nichols, R. L., 1946, McCartys basalt flow, Valencia County, New Mexico: Geol. Soc. America Bull., v. 57, p. 1049-1086.

Geology of McCartys basalt flow of probable Recent age. The volcanics are in the central part of Grants uranium region and in the area bordering it on the south. Subjects include general aspects of the flow; age of the flow; drainage changes effected by the flow; climate at time of extrusion; flow mechanism; cavities, spatter cones, and cracks; description, origin, time of drainage of tubes, and time of formation of collapse depressions, volume of the drained lava, collapse depressions and kipukas in cross section; pressure ridges, description, formation, crustal shortening, origin, domical theory for origin of pressure ridges.

Illustrations: location maps; map of areal distribution of flows; topographic maps of volcanic features; map of distribution of volcanic features; geologic section; photographs; diagrammatic sketches, plan and section views.

223 Noble, E. A., 1960a, Water of compaction as an ore-forming fluid (abs.): Geol. Soc. America Bull., v. 71, p. 2038.

Discusses origin of "sedimentary-type" uranium deposits in general, class including deposits of Grants uranium region. Author suggests that elements are acquired by connate water during diagenesis of sediments and carried along as the water is expelled during compaction of the source beds, and that mineral belts may represent zones in which pressure conditions were favorable for deposition of ore.

224 Noble, E. A., 1960b, Genesis of uranium belts of the Colorado Plateau: *in* Internat. Geol. Cong., 21st, Copenhagen 1960, sec. 15, pt. 15, Genetic problems of uranium and thorium deposits, p. 26-39.

Hypothetical consideration of origin of control of the localization of sandstone-type uranium deposits in belts on the Colorado Plateau, including Grants uranium region. Postulates that uranium was made available to ground waters by decomposition of uranium-bearing rocks and was transported down a pressure gradient in underground aquifers; when the fluid pressure decreased to a point below which chemical disequilibrium occurred, precipitation of large quantities of uranium resulted; fluid potential gradients originated from the compression of shale units brought about by gravitational compaction; genesis of belts and constituent deposits is analogous to origin of oil pools. Subjects include history of recognition of belts; genesis of uranium belts; source, transportation, and deposition of uranium; Uravan uranium belt; Lisbon Valley belt; Southern San Juan basin mineral belt. Author suggests that the localizing of Morrison mineralization in Grants uranium region may be related to uranium-bearing fluids migrating from San Juan basin under the influence of a pressure head brought about by gravitational compaction during subsidence of the basin in Late Jurassic and Cretaceous time.

Illustrations: small-scale geologic maps; geologic sections; stratigraphic chart.

225 Northrop, S. A., 1959, Minerals of New Mexico (revised ed.): Albuquerque, New Mexico, Univ. New Mexico Press, 665 p.

Pertains to New Mexico mineralogy and mining including Grants uranium region. Records and citations appear to be complete through 1956, some (then unpublished) information dates into 1957, and figures for total value of New Mexico mineral production are complete through 1958. Comprises summary of highlights in history of New Mexico mineralogy and mining; chronological list of minerals recently discovered in New Mexico; summary of unpublished records of occurrence; list of minerals which have been analyzed; list of minerals constituting museum specimens and districts furnishing such specimens; list of outstanding minerals; list of fluorescent minerals; list of radioactive minerals; accepted name of species and certain

popular or obsolete mineral names; composition expressed by words and chemical formula; physical properties; descriptions of varieties or subspecies; records of occurrence; list of districts, subdistricts, camps, and synonyms and name of county in which districts are located.

Illustrations: small-scale map of New Mexico showing location of the 177 recognized mining districts.

226 Northrop, S. A., and Hill, Arlette, 1961, Geologic map of the Albuquerque country; *in* New Mexico Geol. Soc. Guidebook 12th Field Conf., Albuquerque Country (in pocket).

Small-scale (1/380, 160), colored geologic map of area of about 1050 square miles in northwestern New Mexico. As a coordinate for location, Albuquerque is in the NW corner of the SE¼ of the map, which includes the eastern part of Grants uranium region.

227 O'Sullivan, R. B., and Beaumont, E. C., 1957, Preliminary geologic map of western San Juan and McKinley Counties, New Mexico: U.S. Geol. Survey Oil and Gas Inv. Map 190.

Small-scale (1/125,000) geologic map of the northwestern part of New Mexico, including northwestern nose of Zuni uplift in southeastern part of map, areas to the west as far as the Arizona line, and areas to the north as far as the Colorado line. As a further coordinate for location, Gallup, New Mexico, is west of center near the south boundary of the map.

228 Perry, B. L., 1963, Limestone reefs as an ore control in the Jurassic Todilto Limestone of the Grants district: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 150-156.

Studies "reefs" in Todilto Limestone and distribution of "primary" uranium mineralization with respect to these structures around Ambrosia Lake, central part of Grants uranium region. Subjects include local stratigraphy of Todilto Limestone; "reef" structures, forms, dimensions, component parts, and variations in type; "reef" sedimentology; "off-reef" flexures (folds in strata adjacent to reef); distribution of mineralization with respect to component parts of "reef" and types of "reef" structure; origin of "reef" structures; origin of "off-reef" flexures.

Illustrations: photographs; diagrammatic maps and sections.

229 Perry, V. D., 1961, The significance of mineralized breccia pipes: Mining Eng., v. 13, p. 367-376.

Studies mineralized breccia pipes, such as the Woodrow pipe uranium deposit of Laguna district, eastern part of Grants uranium region. Includes pipe's form of structure and condition of enclosed strata; local distribution of igneous rocks; origin of the pipe structure; source of the uranium. Author suggests "that the pipe may be related to an underlying intrusive plug, that the uranium mineralization is hydrothermal, and that Woodrow pipe or others like it may have been primary conduits for the extraordinary concentration of uranium in the flat sandstone beds of the Jackpile mine."

Illustrations: photographs; diagrammatic sketches.

230 Peters, W. C., 1956, Uranium-fluorite deposits: Uran. Inf. Digest, v. 3, no. 8, p. 7-8, 25, 30.

Reviews association of uranium and fluorite, including Todilto uranium deposits of Grants, New Mexico, area. Described are classes of western fluorspar deposits, both radioactive and nonradioactive; distinct types of fluorite deposits; examples or uranium-fluorite bodies; types of Todilto ores and associations of fluorite and ore; mineral assemblages; textural relation of fluorite and uranium minerals; structural control of fluoritic ore bodies; sedimentary controls of mineralization; directional orientation of ore bodies; stratigraphic distribution of ore.

231 Peterson, J. A., and others, 1965, Sedimentary history and economic geology of San Juan basin: *in* Am. Assoc. Petroleum Geologists Bull., v. 49, Rocky Mountain sedimentary basins, p. 2076-2119.

Stratigraphy, structural geology, and economic geology of San Juan basin, including Grants uranium region. Authors treat stratigraphy especially and review entire section of the region, Precambrian through Eocene.

Illustrations: small-scale geologic map; stratigraphic correlation chart; small-scale structure-contour map; small-scale isopach and total porous sandstone maps; small-scale, regional, subsurface, geologic sections; fence diagram.

232 Rapaport, Irving, 1952, Interim report on the ore deposits of the Grants district, New Mexico: U.S. Atomic Energy Comm. RMO-1031, 19 p.

Summarizes uranium geology of Grants uranium region as known at time of publication. Notes mineralization in Todilto, Morrison, and Dakota formations. Subjects include mineral assemblages of deposits; guides to ore; paragenesis and sequence of geologic events determining present form and position of Todilto ore deposits; genesis of structure; genesis of deposits.

233 Rapaport, Irving, 1963, Uranium deposits of the Poison Canyon ore trend, Grants district: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 122-135.

Uranium geology of Poison Canyon trend (Morrison mineralization) part of Ambrosia Lake district in central part of Grants uranium region. Subjects include stratigraphy; structure; individual deposits of trend; classification of ore deposits based on relation of ore to structural features and carbonaceous matter; "San Mateo mineral hiatus" and its significance; genesis of deposits.

Illustrations: small-scale map showing location of deposits; large-scale maps of individual deposits; large-scale geologic section of one of the mines.

234 Rapaport, Irving, and others, 1952, Jurassic rocks of the Zuni uplift: U.S. Atomic Energy Comm. RMO-642, 47 p.

Reconnaissance studies of geology of Grants uranium region and bordering areas to the south. Emphasizes relations in western part of the region and in Zuni Mountains, flanking the region on the south. Subjects include stratigraphy; structural geology; distribution of uranium mineralization with respect to stratigraphic division; existence of a positive east-west structural element south of the Jurassic sedimentary basin; southward "Jurassic overlap" of Silver (1948); depositional environments of formations; origin of "sandstone pipes"; origin of Todilto folds; origin of faults and joint patterns; origin of local folding; magnitude of lower Cretaceous uplift of the Zuni area with respect to the Laramide (?) uplift of Zuni Mountains; genesis of "Zuni uplift."

Illustrations: small-scale geologic sections and maps; stratigraphic chart; measured stratigraphic sections; stratigraphic correlations.

235 Read, C. B., and Wanek, A. A., 1967, Stratigraphy of outcropping Permian rocks in parts of northeastern Arizona, and adjacent areas (excerpts): *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 122-124.

Paleozoic formations exposed in areas bordering the western part of Grants uranium region on the south and west. Subjects include nomenclature and correlation of units; contacts of divisions; thickness of formations; lithology of units.

Illustrations: stratigraphic table of the Zuni Mountains and Defiance uplift sections.

236 Read, C. B., and others, 1967, Second-day road log from Gallup through the Zuni Mountains to Thoreau and return to Gallup via Smith Lake, Mariano Lake, and Pinedale: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 97-118.

Geologic information pertaining to western part of Grants uranium region and bordering areas to the south. Describes local stratigraphic section, including particulars of the stratigraphy of rocks directly overlying the Precambrian in the center of Zuni uplift, and Zuni structure.

Illustrations: photographs of geologic features.

237 Reinhardt, E. V., 1952, The distribution of uranium-vanadium deposits in the Colorado Plateau relative to Tertiary intrusive masses: U.S. Atomic Energy Comm. RMO-816, 16 p.

Distribution of uranium-vanadium deposits in the Four Corners region in relation to various igneous masses, including deposits of Grants uranium region, and characteristics of distribution.

Illustrations: small-scale geologic maps.

238 Renault, Jacques, 1968, Variation in some Quaternary basalts in New Mexico (abs.): Geol. Soc. America Program with abstracts 1968 annual meeting, p. 247.

Description of composition of young basalts in New Mexico including the McCartys field of the Grants area and consideration of origin of the lavas.

239 Renault, Jacques, 1970, Major-element variations in the Potrillo, Carrizozo,

and McCartys basalt fields, New Mexico: New Mexico Bureau Mines Mineral Resources Circ. 113, 22 p.

Studies areal variations in composition of Potrillo, Carrizozo, and McCartys volcanic fields· Quaternary basalts of New Mexico. The McCartys flows occur in central part of Grants uranium region and areas bordering it on the south. Investigations characterize the mean composition of each of the volcanic fields and correlate these with respective tectonic settings. Subjects include methods of field sampling; analytical procedures; oxide variation in the basalts; genesis of the basalts; nature of parent magma; extent of differentiation of basalts; source of basaltic magma; degree of tectonism as an implication of inferred source for the magma.

Illustrations: location maps; figures showing distribution of chemical constituents in lavas; MFA diagram; graphic representation of variations of titania content with solidification index; chart showing age of basalts; tables of analyses.

240 Repenning, C. A., and Irwin, J. H., 1954, Bidahochi Formation of Arizona and New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1821-1826.

Stratigraphic study of Bidahochi Formation (Pliocene) of areas bordering Grants uranium region on the west. Subjects include distribution and lithologic character (Bidahochi Formation) and relationship to adjacent areas.

Illustrations: small-scale distribution map; measured section.

241 Repenning, C. A., and others, 1958, Tertiary stratigraphy of the Navajo country: *in* New Mexico Geol. Soc. Guidebook 9th Field Conf., Black Mesa basin, p. 123-129.

Stratigraphic description of Chuska Sandstone and Bidahochi Formation of northeast Arizona and adjacent parts of New Mexico, Colorado, and Utah, including westernmost parts of Grants uranium region. Subjects include age, contacts, divisions, facies, distribution, thickness, lithology (including sedimentary structures), and depositional environments.

Illustrations: small-scale geologic maps; geologic section; photograph.

242 Ridge, J. D., 1972, Annotated bibliographies of mineral deposits in the western hemisphere: Geol. Soc. America Mem. 131, 681 p.

These bibliographies and the notes that accompany them show where the ore deposit is, why a certain age date has been assigned to it, and why it has been given the position assigned to it in the modified Lindgren classification. Indexes in the back of the book list deposits alphabetically, by minerals produced, by age of mineralization, and by position in the modified Lindgren classification, and include an author index. Sketch maps show approximate locations of the ore deposits discussed. The author favors a hydrothermal source for uranium.

243 Rosenzweig, Abraham, 1961, Mineralogical notes on the uranium deposits of the Grants and Laguna districts: *in* New Mexico Geol. Soc. Guidebook 12th Field Conf., Albuquerque country, p. 168-171.

Geology of uranium deposits of the central and eastern parts of Grants uranium region. Subjects include deposits in Todilto Limestone; Poison Canyon deposit, as a typical sandstone-type deposit of the Grants area; the Jackpile deposit, as a typical sandstone deposit of the Laguna area; Woodrow deposit, as an atypical sandstone deposit of Laguna area; major ore minerals; nonuranium minerals of special interest; check list of uranium and vanadium minerals of the area.

244 Rosenzweig, Abraham, and others, 1954, Widespread occurrence and character of uraninite in the Triassic and Jurassic sediments of the Colorado Plateau: Econ. Geology, v. 49, p. 351-361.

Early discoveries and studies of the distribution of "black" uranium mineralization (uraninite) in sandstone deposits of the Colorado Plateau, including Grants uranium region and ores of Todilto Limestone. Subjects include geographic and stratigraphic location of occurrences of uraninite; form of deposits; lithology of host rock; particulars of distribution of mineralization; physical properties of the "Plateau" uraninites; types of uranium recognized deposits; paragenetic relations; significance of association of pyrite and organic matter with uraninite.

Illustrations: photomicrographs; tables.

245 Rosholt, J. N., Jr., 1959, Natural radioactive disequilibrium of the uranium series: U.S. Geol Survey Bull. 1084-A, p. 1-30.

State of radioactive equilibrium in geologic samples from mineralized localities in the

United States and Canada, two from deposits of Grants uranium region. Paper discusses results of analyses of disequilibrium samples; illustrates a proposed classification of disequilibrium patterns; studies these patterns as clues to geochemical history of samples and the deposits; points out some difficulties of comparing radioactivity and chemical analyses of uranium.

Illustrations: representations of classification of natural radioisotopes into groups; anomalies in comparison of eU to U; types of disequilibrium classified by ratios of radioisotopes; age of uranium deposition in years as a function of the ratios of (equivalent) daughter products to uranium; tables of analyses.

246 Rosholt, J. N., Jr., 1960, A study of uranium mineralization in sandstone-type ore deposits: *in* U.S. Geol. Survey Prof. Paper 400-B, Short papers, p. 41-42.

Describes four types of uranium migration and deposits, presumably Morrison, of the Ambrosia Lake area, central part of Grants uranium region.

247 Russel, R. T., 1958, Relationship of uranium ore deposits to petroleum- and gas-bearing structures: *in* United Nations Internat. Conf. Peaceful Uses Atomic Energy 2nd Proc., Geneva, v. 2, p. 358-366.

Description of uranium deposits in Wyoming, Colorado, Utah, New Mexico, Texas, and Oklahoma and mineralization of Ambrosia Lake trend, Ambrosia Lake district, central part of Grants uranium region. Subjects include distribution of ore with respect to structural elements; stratigraphic particulars, organic matter; genesis of deposits.

Illustrations: generalized, small-scale structure map of the Colorado Plateau, showing location of uranium deposits and oil and gas fields in Ambrosia Lake area.

248 Santos, E. S., 1963, Relation of ore deposits to the stratigraphy of host rocks in the Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 53-59.

Study of the relation of uranium mineralization and stratigraphy of Westwater Canyon Member (Morrison Formation) in Ambrosia Lake area, central part of Grants uranium region; mineralization of Ambrosia Lake trend. Subjects include local stratigraphy of Westwater Canyon Member; form of ore bodies; distribution of mineralization with respect to sedimentary particulars in trend ore bodies; calcite cement; distribution of mineralization across Ambrosia Lake trend, from north to south with respect to stratigraphic position in Westwater Canyon Member; distribution of mineralization with respect to thickness in Ambrosia Lake and Poison Canyon trends; distribution of mineralization as Ambrosia Lake trend with respect to corresponding conspicuous variations in thickness and facies of Westwater Canyon Member.

Illustrations: small-scale map of Ambrosia Lake area showing Ambrosia Lake and Poison Canyon trends; large-scale correlation section showing distribution of ore in Westwater Canyon Member in Ambrosia Lake and Poison Canyon trends; large-scale correlation sections comparing stratigraphy of Westwater Canyon Member in Ambrosia Lake trend and stratigraphy of the Member in adjacent barren ground.

249 Santos, E. S., 1966a, Geologic map of the San Lucas Dam quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-516.

Geologic map, topographic base, of a 7½-minute quadrangle in Ambrosia Lake area.

250 Santos, E. S., 1966b, Geologic map of the San Mateo quadrangle, McKinley and Valencia Counties, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-517.

Geologic map, topographic base, of a 7½-minute quadrangle in Ambrosia Lake area.

251 Santos, E. S., 1970, Stratigraphy of the Morrison Formation and structure of the Ambrosia Lake district, New Mexico: U.S. Geol. Survey Bull. 1272-E, 30 p.

Stratigraphy of Morrison Formation and structural geology of Ambrosia Lake district, central part of Grants uranium region. Stratigraphic subjects include development of nomenclature; regional stratigraphy; local stratigraphy of Recapture Member; local stratigraphy of Westwater Canyon Member; stratigraphy of "Poison Canyon Sandstone" (considered here as part of the Westwater); local stratigraphy of Brushy Basin Member. Structural subjects include structural setting; post-Dakota folds; pre-Dakota folds; intraformational folds of undetermined age in Todilto Limestone; faults and joints; "collapse structures."

Illustrations: small-scale structure-contour map, small-scale isopach and lithofacies map of the Westwater; geologic sections; and orientations of folds, joints, and faults.

252 Santos, E. S., and Thaden, R. E., 1966, Geologic map of the Ambrosia Lake quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Quad. Map GQ-515.

Geologic map, topographic base, of a 7½-minute quadrangle in Ambrosia Lake area.

253 Saucier, A. E., 1967, The Morrison Formation in the Gallup region: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 138-144.

Stratigraphic study of Morrison Formation in the westernmost part of Grants uranium region. Subjects include gross lithologic aspect of members; contacts; variations in thickness; facies and other divisions; various details of lithology including coloration of sediments and mineral composition; crossbedding directions; genesis of members and facies.

Illustrations: small-scale isopach maps of Recapture and Westwater Canyon members in the Gallup area; correlation of columnar sections; electric-log section across the Gallup Sag.

254 Schlee, J. S., 1957, Petrology of the Jackpile Sandstone, New Mexico (abs.): Geol. Soc. America Bull., v. 68, p. 1793.

Study (in sketch) of Jackpile Sandstone of Laguna district, eastern part of Grants uranium region. Subjects include stratigraphic occurrence of the Jackpile; economic importance of the division; distribution of unit with respect to structural features; petrography of the Jackpile; stratigraphic distribution of petrographic classes of sandstone in the Jackpile; the depositional environment of the Jackpile.

255 Schlee, J. S., 1959, Sandstone pipes of the Laguna area, New Mexico (abs.): Geol. Soc. America Bull., v. 70, p. 1669.

Description (in sketch) of "sandstone pipes" of Laguna area (eastern part of Grants uranium region), their distribution with respect to structural elements of area, and their origin according to concepts of author.

256 Schlee, J. S., 1963, Sandstone pipes of the Laguna area, New Mexico: Jour. Sed. Petrology, v. 33, p. 112-123.

Studies "sandstone pipes" in Jurassic rocks of Laguna area, eastern part of Grants uranium region. The "pipes" are pillarlike bodies of sandstone as much as 150 ft in diameter and 200 ft in height. Subjects include distribution of the pipes; description of pipes; source of sandstone within the pipe; origin of sandstone pipes.

Illustrations: small-scale geologic map; stratigraphic section showing vertical distribution of pipes; geologic sections; schematic plan views of internal structure in sandstone pipes; photograph; table of petrographic data; diagrammatic sections illustrating origin of pipes.

257 Schlee, J. S., and Moench, R. H., 1961, Properties and genesis of "Jackpile" Sandstone, Laguna, New Mexico: *in* Am. Assoc. Petroleum Geologists, Geometry of sandstone bodies, Tulsa, Oklahoma, p. 134-150.

Stratigraphic study of the upper Morrison of the eastern part of Grants uranium region. Subjects include stratigraphy and sedimentology of "Jackpile" Sandstone; structural elements of pre-Dakota age; depositional environment; prevailing direction of stream flow; source of sediment; effects of tectonism; subsidence and structural control of stream flow; modern and older analogs of deposition.

Illustrations: small-scale geologic map; schematic maps; figures showing fluvial, sedimentary patterns of bodies similar to the "Jackpile"; chart comparing "Jackpile" and fluvial deposits; graphs; photomicrographs.

258 Schlee, J. S., and Moench, R. H., 1963a, Geologic map of the Moquino quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-209.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

259 Schlee, J. S., and Moench, R. H., 1963b, Geologic map of the Mesita quadrangle, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-210.

Geologic map, topographic base, of a 7½-minute quadrangle in Laguna area.

260 Schnabel, R. W., 1955, The uranium deposits of the United States: U.S. Geol. Survey Mineral Inv. Resource Appraisals Map MR-2.

Sheet comprised of a map showing location of uranium deposits, table of deposit names, text describing geology deposits and prospects for future development. The base is an outline

map of the conterminous United States and constituent states and counties on a grid of degrees of latitude and longitude, scale 1/5,000,000.

261 Sharpe, J. V. A., 1955, Uranium deposits in the Morrison Formation, Church Rock area, McKinley County, New Mexico: U.S. Atomic Energy Comm. RME-79, 19 p.

Field study of distribution of uranium deposits in Morrison Formation of Church Rock area, westernmost part of Grants uranium region. Subjects include local Morrison stratigraphy; distribution of uranium mineralization; uranium prospects, including the Foutz No. 1 deposit; ore guides for the area; genesis of limonite in the area; genesis of uranium deposits in the Westwater of the area; relation of uranium and limonite mineralization.

Illustrations: small-scale geologic maps; correlations of stratigraphic sections; chart of stratigraphic information for the section.

262 Shawe, D. R., 1966, Zonal distribution of elements in some uranium-vanadium roll and tabular ore bodies on the Colorado Plateau: *in* U.S. Geol. Survey Prof. Paper 550-B, Short papers, p. 169-171.

Study of distribution of uranium, vanadium, and selenium in certain uranium deposits of Colorado, Utah, and New Mexico. Includes deposits of Ambrosia Lake and Poison Canyon trends, Ambrosia Lake district, central part of Grants uranium region. Subjects include physical characteristics of roll-type and tabular-type ore bodies; general form and degree of oxidation of individual deposits; distribution of U, V, and Se in suites of samples; similarity in zonal distribution of elements across both roll- and tabular-type ore bodies; compatibility of patterns of distribution with a theory that ore and other elements were precipitated in an interface between two solutions or one edge of tabular ore layers.

Illustrations: geologic sections and chemical analyses of ore bodies; analyses of suites of samples from ore bodies.

263 Shawe, D. R., and Granger, H. C., 1965, Uranium ore rolls—an analysis: Econ. Geology, v. 60, p. 240-250.

Discussion of uranium ore rolls Wyoming, Colorado, and New Mexico and review of literature pertinent to other areas. Subjects include uranium deposits of Shirley Basin, Wyoming; Rifle, Colorado; Ambrosia Lake, New Mexico; and Uravan, Colorado; northeastern Black Hills, South Dakota; southwestern Black Hills, South Dakota; Powder River Basin, Wyoming; and USSR.

264 Shoemaker, E. M., 1954, Structural features of southeastern Utah and adjacent parts of Colorado, New Mexico, and Arizona: *in* Utah Geol. Society Guidebook to the geology of Utah, no. 9, Uranium deposits and general geology of southeastern Utah, p. 48-69.

Structural geology of the central part of the Colorado Plateau, including Grants uranium region. (The paper appears to be an early edition of Shoemaker, 1956.) Subjects include structural features; structures produced by igneous activity; tectonic history; origin of major uplifts of the central Colorado Plateau; author's hypothesis of "ice jam mechanics."

Illustrations: small-scale geologic map; photograph.

265 Shoemaker, E. M., 1956a, Structural features of the central Colorado Plateau and their relation to uranium deposits: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 155-170.

Structural geology of the central part of the Colorado Plateau including Grants uranium region with special reference to the occurrence of uranium deposits. Similar to Shoemaker, 1954. Subjects include relation of uranium deposits to structure; age of the uranium deposits, relation to salt anticlines; relation to faults outside the salt anticline region; uranium deposits associated with volcanic structures.

Illustrations: small-scale tectonic sketch map; map of salt plug structure; geologic section taken through a uranium deposit.

266 Shoemaker, E. M., 1956b, Occurrence of uranium in diatremes on the Navajo and Hopi reservations, Arizona, New Mexico, and Utah: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 179-185.

Uranium mineralization in young sediments near diatremes of the western extremity of Grants uranium region and areas beyond. Subjects include structure of diatremes; composi-

tion of volcanic rocks; uranium deposits, mineralogy, chemical compositions, grade, size, features of distribution, and source.

Illustrations: small-scale geologic map; diagrammatic views of diatremes.

267 Shomaker, John, 1967, The Mount Taylor volcanic field: a digest of the literature: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 195-201.

Reviews of geology of Mt. Taylor volcanic field in central and eastern parts of Grants uranium region.

Illustrations: small-scale geologic map of the region; sketches and photographs of various features.

268 Silver, Caswell, 1948, Jurassic overlap in western New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 68-81.

Stratigraphy of the "Jurassic" section especially (Wingate-Morrison, inclusive) of an area south of Laguna, including parts of the eastern end of Grants uranium region and tracts bordering eastern end on the south. Subjects include Chinle Formation (Triassic); Wingate Sandstone (Jurassic); Todilto Formation (Jurassic); Morrison formation (Jurassic); Dakota (?) sandstone (Cretaceous); depositional environment of formations; sedimentary and structural relations.

Illustrations: map showing location of measured sections; correlation of graphic sections of Mesozoic strata; photographs; measured section.

269 Silver, Caswell, and Hoover, W. B., 1951, Geologic map of the San Juan basin (compilation): *in* New Mexico Geol. Soc. Guidebook 2nd Field Conf., South and west sides of the San Juan basin, New Mexico and Arizona (in pocket).

Small-scale geologic map of San Juan basin region, including Grants uranium region.

270 Smith, C. T., 1951, Problems of Jurassic stratigraphy of the Colorado Plateau and adjoining regions: *in* New Mexico Geol. Soc. Guidebook 2nd Field Conf., South and west sides of the San Juan basin, New Mexico and Arizona, p. 99-102.

Jurassic stratigraphy around Colorado Plateau, including Grants uranium region. Subjects include questions and problems connected with the stratigraphy; sedimentary characteristics of the section; distribution of principal groups of Jurassic formations; distribution of positive areas during Jurassic time; influence of particular "highs" on sedimentation.

Illustrations: small-scale isopach maps of Chinle Formation, Glen Canyon Group, and San Rafael Group; small-scale distribution map of part of Morrison Formation.

271 Smith, C. T., 1954, Geology of the Thoreau quadrangle, McKinley and Valencia Counties, New Mexico: New Mexico Bureau Mines Mineral Resources Bull. 31, 36 p.

General geology of a 15-minute quadrangle on the southern border of the west-central part of Grants uranium region around Thoreau. Subjects include stratigraphy; structural geology; igneous rocks; occurrences of uranium mineralization; description of formations; definition of (new) Thoreau Formation; definition of new members of Morrison Formation; overall structure and description of chief faults of the area; origin of formations; relation of structural features to central Zuni uplift; relation of basalts to Mt. Taylor volcanics.

Illustrations: small-scale (1/48,000) geologic map (planimetric base) of the 15-minute Thoreau quadrangle (includes geologic sections); stratigraphic log of a well section.

272 Smith, C. T., 1955, Uranium occurrences of the Colorado Plateau: *in* Four Corners Geol. Soc. Guidebook 1st Field Conf., Geology of parts of Paradox, Black Mesa and San Juan basin, p. 169-176.

Reviews of stratigraphic occurrence of uranium mineralization on the Colorado Plateau and potential for new discoveries. The region encompasses Grants uranium region. Subjects include regional stratigraphy; distribution of known mineralization with respect to formations of the section; characteristics of sandstone host rocks as particulars apparently favorable for uranium mineralization.

Illustrations: chart of stratigraphic nomenclature; small-scale location map of uranium occurrences.

273 Smith, C. T., 1957, Geology of the Zuni Mountains, Valencia and McKinley

Counties: *in* Four Corners Geol. Soc. Guidebook 2nd Field Conf., Geology of southwestern San Juan basin, p. 53-61.

Description of geology of the western part of Grants uranium region and bordering areas to the south. Subjects include local stratigraphy; structural geology; stratigraphic nomenclature; genesis of formations; genesis of Zuni uplift.

Illustrations: small-scale map of Zuni Mountains.

274 Smith, C. T., 1958, Geologic map of Inscription Rock fifteen-minute quadrangle: New Mexico Bureau Mines Mineral Resources Geol. Map 4.

Small-scale (1/48,000) geologic map (planimetric base) of a 15-minute quadrangle southwest of the border of the western part of Grants mineral belt, southwest flank of Zuni Mountains. Rocks mapped range in age from Precambrian (core of Zuni Mountains) to Cretaceous (Mesaverde Group) and possibly include young basalts.

275 Smith, C. T., 1959a, Geologic map of Foster Canyon quadrangle, Valencia and McKinley Counties, New Mexico: New Mexico Bureau Mines Mineral Resources Geol. Map 9.

Small-scale (1/48,000) geologic map (planimetric base) of a 15-minute quadrangle on the border of the western part of Grants uranium region, near Fort Wingate. Rocks mapped range in age from Precambrian (core of Zuni Mountains) to Cretaceous (Dakota Formation).

276 Smith, C. T., 1959b, Jurassic rocks of the Zuni Mountains: *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 74-80.

Reviews of stratigraphy of the Jurassic section, Entrada-Morrison, inclusive, of the western part of Grants uranium region and bordering areas to the south. Author treats divisions, contacts, thicknesses, distribution, facies, and lithology of formations, as well as depositional environments of formations.

Illustrations: nomenclature chart of Jurassic formations of Zuni Mountains; fence diagrams of upper Triassic and Jurassic rocks; photographs of stratigraphic features.

277 Smith, C. T., 1961, Triassic and Jurassic rocks of the Albuquerque area: *in* New Mexico Geol. Soc. Guidebook 12th Field Conf., Albuquerque country, p. 121-128.

Stratigraphy of Triassic and Jurassic rocks in the Albuquerque area (includes significant mention of relation in Grants uranium region). Section on Triassic rocks includes descriptions of Chinle Formation of Zuni Mountains and of Dockum Group around New Mexico; on Jurassic rocks includes description of Entrada, Todilto, Summerville, Morrison, and Cow Springs formations in the Albuquerque and adjoining areas; includes identifications of dinosaur bones from localities of Grants uranium region in the handling of Morrison Formation; Triassic-Jurassic sedimentational history of the Albuquerque area.

Illustrations: small-scale geologic map of Albuquerque area; correlation chart of Triassic rocks; correlation chart of Jurassic rocks.

278 Smith, C. T., 1967, Jurassic stratigraphy of the north flank of the Zuni Mountains: *in* New Mexico Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 132-137.

Jurassic stratigraphy of the western part of Grants uranium region and bordering areas to the south. Subject includes general description of formations of the section; definition of a new member of the Morrison, Casamero Member; consideration of genesis of formations, especially depositional environments.

Illustrations: photographs; measured section of Casamero Member at type locality.

279 Smith, C. T., 1970, Notes on the geology of the Colorado Plateau: *in* Nat. Assoc. Geol. Teachers, Southwest Section Guidebook, Four Corners, Colorado Plateau, Rocky Mountain region, p. 21-30.

Sketches stratigraphy (Precambrian-Quaternary), tectonic history, and history of development of mineral resources (vanadium, uranium, petroleum, and coal) of the Colorado Plateau; mentions relations in Grants uranium region.

Illustrations: chart of stratigraphic nomenclature; map of the Plateau showing sectional boundaries.

280 Smith, M. C., Jr., 1967, The AEC and the Grants mineral belt: *in* New Mexico

Geol. Soc. Guidebook 18th Field Conf., Defiance-Zuni-Mt. Taylor region, p. 184-187.

History of uranium industry in USA with emphasis on developments in Grants uranium region; presented in context with evolving activities of the AEC.

281 Squyres, J. B., 1963, Geology and ore deposits of the Ann Lee mine, Ambrosia Lake area: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 90-101.

Geology and uranium deposits of Ann Lee mine. Ambrosia Lake district, central part of Grants uranium region, in Westwater Canyon Member of Morrison Formation (part of Ambrosia Lake trend). Subjects include local Morrison stratigraphy; structural features of the mine area; form, dimensions, and orientation of ore bodies; character of ore boundaries; stratigraphic distribution of deposits; distribution of mineralization with respect to bedding, thickness, sedimentary structures, textures, and carbonaceous material; distribution of mineralization with respect to regional dip and fractures; the outward aspect, grade, and variation of grade, element assemblage and distribution of chief elements in the ore; accessory mineral assemblage and distribution; relative age of elements in the ore; character of transporting solution; direction of transport; character of depositing medium; possibility of multiple periods of deposition.

Illustrations: graphic section of Westwater Canyon sandstone; large-scale geologic sections of ore bodies showing distribution of elements; large-scale map showing areal distribution of ore; photographs.

282 Squyres, J. B., 1970, Origin and depositional environment of uranium deposits of the Grants region, New Mexico: Stanford University, Unpub. Ph.D. dissert.

Comprehensive study of Morrison uranium deposits of Ambrosia Lake district, central part of Grants uranium region. Subjects include local stratigraphy (Morrison Formation, especially); local structural geology; petrology and mineralogy of Westwater Canyon and Brushy Basin members of Morrison Formation; mineralization in the Morrison; genesis of Morrison uranium deposits of the area.

Illustrations: geologic maps; diagrammatic sketches; photographs; tables.

283 Squyres, J. B., September 1972, Uranium deposit of the Grants region, New Mexico: Wyoming Geol. Assoc., Earth Sci. Bull., p. 3-12.

Summary and restatement of the dissertation described above.

Illustrations: maps; diagrammatic sketches; photographs.

284 Stieff, L. R., and others, 1956, Coffinite, a uranous silicate with hydroxyl substitution—a new mineral: Am. Mineralogist, v. 41, p. 675-688.

Naming and description of a "new," black, uranium mineral (coffinite) of common occurrence in uranium deposits, including those of Grants uranium region. Subjects include occurrence of coffinite; physical properties; optical properties; X-ray diffraction; chemical analyses; synthesis; alpha-plate and leaching studies; infrared analyses.

Illustrations: photomicrographs; locality table; tables of analyses; infrared absorption spectragrams.

285 Stocking, H. E., and Page, L. R., 1956, Natural occurrence of uranium in the United States—a summary: *in* U.S. Geol. Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 5-12.

Sketch of geology of types of occurrence of uranium ore in the United States; includes igneous rock; vein; terrestrial, clastic sedimentary; chemical precipitate; coal; marine sedimentary; petroleum and asphaltites. Authors include summary of aspects of Todilto deposits, shape, structural controls, and mineralogy.

286 Stokes, W. L., 1961, Fluvial and eolian sandstone bodies in Colorado Plateau: *in* Am. Assoc. Petroleum Geologists, Geometry of sandstone bodies, Tulsa, Oklahoma, p. 151-178.

Stratigraphy of nonmarine formations of the Late Paleozoic-Jurassic section of a region centering in the "Four Corners" generally beyond the limits of Grants uranium region. Reviews theoretical considerations relevant to the distribution of the sediments: tectonic setting; sediment source; climatologic influences; stratigraphic aspects of eolian formations of the section (distribution, thickness, sedimentary structures, textures, mineral composition, and environments of deposition); stratigraphic aspects of fluvial sandstones, especially members of

Chinle Formation and Salt Wash Member of Morrison Formation; economic geology of fluvial sandstones; function of fluvial sandstones in genesis of contained deposits; textural occurrence; distribution of mineralization; reviews theories of origin of deposits; considers character of transporting solutions, importance of organic matter in ore-forming processes, and implications of inferences drawn.

Illustrations: small-scale maps of chief geologic features of the Plateau; small-scale maps showing dip directions of cross-strata of formations of various ages; small-scale maps of Salt Wash Member, isopach and sedimentary trend; small-scale section of Shinarump-type channels; large-scale section showing relation of uranium ore and sedimentary particulars in Salt Wash Member; columnar section; photographs.

287 Tanner, W. F., 1965, Upper Jurassic paleogeography of the Four Corners region: Jour. Sed. Petrology, v. 35, p. 564-574.

Sedimentologic study of Upper Jurassic formations (Entrada and Todilto) of Four Corners region, including Grants uranium region. Subjects include cross-bedding; ripple marks; color; Todilto Formation; thickness of Entrada Formation; Entrada sand grains; interfingering of formations and members; environment of deposition of Kayenta, Carmel, and Summerville sediments; chief sedimentary trends of Entrada Formation especially; paleogeography during time of deposition of Upper Jurassic sediments.

Illustrations: representation of cross-bedding data; isopach map of Entrada Formation; maps of distribution of gypsum of Todilto Formation; map of directions of Jurassic crossbedding and Entrada thicknesses; map of Late Jurassic (but pre-Morrison) paleogeography.

288 Tanner, W. F., 1968, Shallow lake deposits, lower part of Morrison Formation (Late Jurassic), northern New Mexico: The Mountain Geologist, v. 5, p. 187-195.

Depositional environment of "lower part of Morrison Formation" in Rio Arriba County, New Mexico, northeast of Grants uranium region. Subjects include Morrison data; ripple marks; modern lake deposits; southern extent.

Illustrations: map; graphic representation of method of interpreting sedimentologic data; graphic representation of grain size distribution in typical Morrison ripple-marked sandstone.

289 Tanner, W. F., 1970, Triassic-Jurassic lakes in New Mexico: The Mountain Geologist, v. 7, p. 281-289.

Depositional environments of formations of the Triassic-Jurassic section (Chinle-Morrison inclusive) of northwestern New Mexico, including Grants uranium region and lake deposits. Subjects include method of determining water depth, wave height, and fetch in sedimentary rocks of lacustrian origin; sedimentary characteristics of Entrada, Todilto, "Lower Morrison sandstones," and "Upper Morrison sandstones," depositional environments of formations; slope of land surface during periods of deposition; wind direction during Entrada time; sedimentary history of northwestern New Mexico during late Triassic and Jurassic time.

Illustrations: palegeographic map; representations of methods of determining particulars of lacustrian environments.

290 Tanner, W. F., 1972, Large gypsum mounds in the Todilto Formation, New Mexico: The Mountain Geologist, v. 9, p. 55-58.

Genesis of "mounds" in the gypsum member of Todilto Formation, including eastern part of Grants uranium region. Subjects include review of stratigraphy of Todilto Formation; review of previously suggested theories of genesis of "mounds"; description of characteristics of mound structures; discussion of genesis of the structures.

Illustrations: outline map showing location of Todilto Formation.

291 Thaden, R. E., and Ostling, E. J., 1967, Geologic map of the Bluewater quadrangle, Valencia and McKinley Counties, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-679.

Geologic map, topographic base, of a 7½-minute quadrangle in the central part of Grants uranium region.

292 Thaden, R. E., and Santos, E. S., 1963, Map showing the general structural features of the Grants district and the areal distribution of the known uranium ore bodies in the Morrison Formation: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 20 and 21.

Small-scale structure map of Ambrosia Lake and bordering areas, central part of Grants uranium region. Includes delineations of ore-grade mineralization as known in 1957.

293 Thaden, R. E., and others, 1966, Geologic map of the Goat Mountain quadrangle, McKinley County, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-518.

Geologic map, topographic base, of a 7½-minute quadrangle in the central part of Grants uranium region.

294 Thaden, R. E., and others, 1967a, Geologic map of the Dos Lomas quadrangle, Valencia and McKinley Counties, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-680.

A geologic map, topographic base, of a 7½-minute quadangle in Ambrosia Lake area, central part of Grants uranium region.

295 Thaden, R. E., and others, 1967b, Geologic map of the Grants quadrangle, Valencia County, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-681.

Geologic map, topographic base, of a 7½-minute quadrangle in the central part of Grants uranium region.

296 Thaden, R. E., and others, 1967c, Geologic map of the Grants SE quadrangle, Valencia County, New Mexico: U.S. Geol. Survey Geol. Quad. Map GQ-682.

Geologic map, topographic base, of a 7½-minute quadrangle in the central part of Grants uranium region.

297 Tipton, W. D., 1961, Geology and uranium mineralization of the Todilto Limestone in the Grants mineral belt (abs.): *in* New Mexico Geol. Soc. Guidebook 12th Field Conf., Albuquerque country, p. 195-196.

Sketch of geology of Todilto uranium deposits of Grants uranium region. Subjects include local stratigraphy of Todilto Limestone; alteration of the limestone; folds; ore mineral assemblages; accessory mineral assemblage; genesis of deposits.

298 Truesdell, A. H., and Weeks, A. D., 1959, Relation of the Todilto Limestone uranium deposits to Colorado Plateau uranium deposits in sandstone (abs.): Geol. Soc. America Bull., v. 70, p. 1689-1690.

Summarizes characteristics of Todilto uranium deposits of the Grants area (central part of Grants uranium region) and compares characteristics with Plateau uranium deposits; concludes that the Todilto and other Plateau deposits are basically similar in mineralogy, occurrence, and origin.

299 Truesdell, A. H., and Weeks, A. D., 1960, Paragenesis of uranium ores in the Todilto Limestone near Grants, New Mexico: *in* U.S. Geol. Survey Prof. Paper 400-B, Short papers, p. 52-54.

Todilto ores of Ambrosia Lake area, central part of Grants uranium region. Subjects include classification of ores (3 types); description of mineral composition, texture, and particulars of distribution; consideration of paragenesis of minerals in the several classes of ore.

Illustrations: photomicrographs; figure of paragenesis of minerals in each of the classes of ore.

300 U.S.A.E.C., 1966, USAEC airborne radiometric reconnaissance in South Dakota and Wyoming, 1952 to 1955: U.S. Atomic Energy Comm. RME-149, 81 p.

Maps showing location of anomalies in item regions. In pocket is an airborne radioactivity survey map of the United States west of Mississippi River showing location of areas surveyed, including those in New Mexico.

301 U.S.A.E.C., 1970, Preliminary reconnaissance for uranium in New Mexico, 1950 to 1958: U.S. Atomic Energy Comm. RME-160, 223 p.

Compilation of "preliminary reconnaissance" reports on localities of reported uranium mineralization in New Mexico. Subjects include location of area; owner or operator of property; history of the mine or property; radioactivity of the area; geology of the location.

Illustrations: geologic maps; sections.

301½ U.S. Geological Survey and others, 1965, Mineral and water resources of New Mexico: New Mexico Bureau Mines Mineral Resources Bull. 87, 437 p.

Summarizes discussion of the use, manner of occurrence, distribution, and outlook for all known mineral commodities in New Mexico. Comprehensive bibliography included. Treatment of uranium deposits includes: review of industry; peneconcordant deposits in Pennsylvanian, Permian, and Triassic rocks, deposits in rocks of Jurassic age, and deposits in rocks of Cretaceous age; tabulation of uranium deposit localities; and tabulation of geologic features and pertinent references for vein deposits.

Illustrations: maps; figures; tables.

302 Vine, J. D., 1962, Geology of uranium in coaly carbonaceous rocks: U.S. Geol. Survey Prof. Paper 356-D, 170 p.

Comprehensive study of geology of uranium in coaly carbonaceous rocks, and in Grants uranium region. Subjects include characteristics of coaly carbonaceous rocks; distribution of uranium deposits in such rocks; uranium distribution related to geologic features; physical and chemical form of uranium in coaly carbonaceous rocks; probable role of such rocks in geochemistry of uranium.

Illustrations: tables and figures; map showing location of pertinent deposits in the USA.

303 Vine, J. D., and others, 1958, The roll of humic acids in the geochemistry of uranium: United Nations Internat. Conf. Peaceful Uses Atomic Energy, 2nd Proc., Geneva, v. 2, p. 187-191.

Describes four types of carbonaceous matter and their geochemical roles in the transportation and concentration of uranium. Subjects include nature of carbonaceous materials; characteristics of humic acids and related substances; humic acids and humates in sedimentary rocks, association of uranium with humic acids and related carbonaceous materials.

Illustrations: diagrammatic representation of the relation among carbonaceous materials; graphic representations contrasting humic and sapropelic organic matter to uranium content oil yield; table.

304 Waters, A. C., and Granger, H. C., 1953, Volcanic debris in uraniferous sandstones and its possible bearing on the origin and precipitation of uranium: U.S. Geol. Survey Circ. 224, 26 p.

Petrologic study of uranium-vanadium ores and host rocks of border areas of western Colorado and northwestern New Mexico relations in Chinle Formation and Morrison Formation (Salt Wash and Brushy Basin members), specifically those beyond Grants uranium region. Subjects include sediments of the formation; ores; distribution of mineralization; genesis of formations; genesis of ores.

Illustrations: chart giving mineral composition of argillaceous samples; large-scale geologic section; illustrations of petrologic relations.

305 Weege, R. J., 1963, Geology of the Marquez mine, Ambrosia Lake area, *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 117-121.

Geology and uranium deposits of Marquez mine, Ambrosia Lake district, central part of Grants uranium region. Deposits are in Poison Canyon Sandstone of Morrison Formation and are part of Poison Canyon trend. Subjects include local stratigraphy; distribution of uranium with respect to stratigraphic and sedimentologic particulars; local sedimentary history; genesis of the deposit.

Illustrations: large-scale plan maps and sections of the deposit.

306 Weeks, A. D., 1956, Mineralogy and oxidation of the Colorado Plateau uranium ores; *in* U.S. Geol Survey Prof. Paper 300, Contributions to the geology of uranium and thorium, p. 187-193.

Primary uranium ores of the Colorado Plateau and alteration of the ores at various stages of oxidation, with localities of Grants uranium region mentioned specifically. Subjects include classification of primary ores; mineralogy; oxidation sequence; mineralogy of oxidized nonvanadiferous uranium ores; relation of oxidation to water table and moisture content of ore.

307 Weeks, A. D., and Garrels, R. M., 1959, Geologic setting of the Colorado Plateau ores: *in* U.S. Geol. Survey Prof. Paper 320, Geochemistry and mineralogy of the Colorado Plateau uranium ores, p. 3-11.

Geology of uranium-producing areas of the Colorado Plateau, with brief mention of deposits and conditions of Grants uranium region. Subjects include sedimentary and igneous rocks of the region; chief structural features; stratigraphic distribution of deposits; geographic and stratigraphic distribution of V/U ratio-type deposits; ore bodies; age of mineralization; conditions at time of ore deposition; questions of origin.

Illustrations: map showing the physiographic divisions and principal structural features of the Plateau; stratigraphic chart of the region.

308 Weeks, A. D., and Thompson, M. E., 1954, Identification and occurrence of uranium and vanadium minerals from the Colorado Plateau: U.S. Geol. Survey Bull. 1009-B, 62 p.

Identification and occurrence of uranium and vanadium minerals of ores from the Colorado Plateau, with mention of mineral localities and ore characteristics of Grants uranium region. Subjects include methods of mineral identification; mineral associations and distribution of types of ore; descriptive mineralogy of uranium and vanadium minerals of the Plateau area.

Illustrations: table of optical properties of uranium minerals; locality table of mines and mining districts.

309 Weeks, A. D., and Truesdell, A. H., 1958, Mineralogy and geochemistry of the uranium deposits of the Grants district, New Mexico (abs.): Econ. Geology, v. 53, p. 932-933; Geol. Soc. America Bull., v. 69, p. 1658-1659.

Description in brief of the geology of uranium deposits of Todilto, Morrison, and Dakota formations of Grants uranium region. Subjects include lithology of host formations; vanadium and molybdenum content of deposits in comparison with those of Uravan, Colorado; content of coalified logs or megascopic fragments of wood in deposits of Uravan, Colorado; distribution of uranium with respect to black organic coatings; mineral assemblages and valence state of uranium in most of the ore; evidence of a reducing environment in Todilto Limestone favorable for precipitation of uranium and vanadium; for Todilto Limestone, the acid insoluble fraction and composition. Authors remark that the acid insoluble fraction of the limestone represents, at least in part, volcanic ash and that leaching of the ash is a possible source of uranium.

310 Weeks, A. D., and others, 1961, Grantsite, a new hydrated sodium calcium vanadyl vanadate from New Mexico and Colorado—a preliminary description: *in* U.S. Geol. Survey Prof. Paper 424-B, Short papers, p. 293.

Describes a "new" vanadium mineral originally discovered in the F-33 mine (Todilto uranium deposit) of the central part of Grants uranium region. Mineral was later found more abundantly in partly oxidized vanadiferous ore elsewhere on the Colorado Plateau.

311 Wengerd, S. A., 1959, Regional geology as related to the petroleum potential of the Lucero region, west-central New Mexico: *in* New Mexico Geol. Soc. Guidebook 10th Field Conf., West-central New Mexico, p. 121-134.

Geologic study of the petroleum potential of a region bordering Grants uranium region on the south. Includes sketch of the general stratigraphy and structural geology of the area; consideration of geologic history, especially late Paleozoic events, paleogeology, and paleogeography.

Illustrations: small-scale map of surface, structural features; paleogeologic map; isopach map of Pennsylvanian marine rocks; geologic section; chart showing stratigraphic column of the area and evaluation of oil potential of formations; figure of local Pennsylvanian section in detail; photographs of geologic features.

312 Whelan, Mark, 1952, Major magnetic anomalies of the Four Corners region: *in* Four Corners Geol. Soc. Guidebook 1st Field Conf., Geological symposium of the Four Corners region, p. 126-127.

Study of magnetic anomalies of the Four Corners area. Region includes areas adjacent to the northern boundary of Grants uranium region.

Illustrations: small-scale map of chief magnetic anomalies of the region.

313 Woodmansee, W. C., 1958, Relationships between sandstone-type uranium deposits and ground water in some uranium-producing areas: United Nations Internat. Conf. Peaceful Uses Atomic Energy, 2nd Proc., Geneva, v. 2, p. 351-357.

Ground-water movement in relation to genesis of certain uranium deposits, including Morrison deposits of Ambrosia Lake area, central part of Grants uranium region. Subjects

include uranium deposits in areas of shallow, perched water tables, in areas of deep ground water, in relation to paleostream channels, in relation to ground water in Tertiary intermontane basins, in relation to ground water in areas where oxidized-unoxidized zones are prevalent; trends of uranium mineralization in relation to directions or patterns of migration of ground water; uranium deposits in areas of fluctuating water tables; Maybell district, Moffatt County, Colorado—possible influence of ground water on the genesis of known ore bodies.

Illustrations: geologic maps and sections.

314 Wright, R. J., 1955, Ore controls in sandstone uranium deposits of the Colorado Plateau: Econ. Geology, v. 50, p. 135-155.

Sedimentary and structural elements appearing to have influenced localizing uranium deposition on the Colorado Plateau. Includes mention of Todilto mineralization of Grants uranium region. Subjects include general geologic setting of the deposits, summary of sedimentary ore controls in the Morrison Formation; characteristics of deposits in other formations; summary of sedimentary ore controls; sandstone uranium ores outside the Colorado Plateau; structural ore controls; similarity to sedimentary copper deposits; genetic implications; genesis and uranium geochemical cycle.

Illustrations: index maps of deposits; small-scale geologic map of Uravan uranium region; small-scale map of outcrop belts of Morrison Formation; stratigraphic table; small-scale map of facies control of an ore belt; idealized cross section of an ore-bearing paleostream channel; generalized geologic section.

315 Wylie, E. T., 1963, Geology of the Woodrow breccia pipe: *in* New Mexico Bureau Mines Mineral Resources Mem. 15, Geology and technology of the Grants uranium region, p. 177-181.

Geology and uranium deposits of Woodrow mine, Laguna district, eastern part of Grants uranium region. The mine is a pipe-type deposit. Mineralization is in sediments of Brushy Basin Member and overlying Jackpile Sandstone, both of Morrison Formation. Subjects include local stratigraphy; pipe structure; distribution of mineralization with respect to sedimentologic and structural particulars; mineral assemblage of the deposit; origin of pipe structure; source of uranium in the deposit.

Illustrations: large-scale plan and section maps of the mine; photograph and autoradiogram from a polished section of ore.

316 Young, R. G., 1960, Dakota Group of Colorado Plateau: Am. Assoc. Petroleum Geologists Bull, v. 44, p. 156-194.

Regional, stratigraphic study of "Dakota Group" (Cretaceous) on the Colorado Plateau, including Grants uranium region. The term "Dakota Group" refers to all the predominantly nonmarine basal Cretaceous deposits of the Colorado Plateau and includes "Burro Canyon Formation." Subjects include nomenclature; Cedar Mountain Formation; Naturita Formation; Mancos Shale; facies; age of deposits; mode of formation; origin of Dakota Group; geologic history.

Illustrations: correlation chart of units of "Dakota Group," correlations of sections; distribution maps; isopach maps; map of channel sandstones in upper part of Cedar Mountain Formation; map showing facies relations; photographs; check lists of fossils.

317 Young, R. G., and Ealy, G. K., 1956, Uranium occurrences in the Ambrosia Lake area, McKinley County, New Mexico: U.S. Atomic Energy Comm. RME-86, 15 p.

Geology and uranium deposits (Morrison) around Ambrosia Lake trend, Ambrosia Lake district, central part of Grants uranium region. Subjects include local stratigraphy; local structural elements; local geologic history; uranium deposits; control of mineralization by precipitating agent (a "petroliferous" residuum); migration of mineralizing solutions; control of migration by faults; origin of bleaching of Westwater Canyon sandstones; genesis of local structural features.

Illustrations: two small-scale (½ mile/inch) geologic maps, one of which shows distribution of bleached and unbleached Westwater Canyon sandstones.

318 Young, R. C., and others, 1956, Surface geologic map of Ambrosia Lake area, McKinley County, New Mexico: U.S. Atomic Energy Comm. Map No. 7.

Small-scale geologic map of area approximately 138 square miles centering near Ambrosia Lake, central part of Grants uranium region.

319 Zitting, R. T., and others, 1957, Geology of the Ambrosia Lake area uranium

deposits, McKinley County, New Mexico: Mines Mag., v. 47, no. 3, p. 53-58.

Reviews geology and studies genesis of Morrison uranium deposits of Ambrosia Lake trend, Ambrosia Lake district, central part of Grants uranium region. Subjects include local stratigraphy (especially Morrison); local structural elements; gross aspects of ore deposits; distribution of mineralization with respect to stratigraphy, structural particulars, "asphaltic residue," and color of host rock; source of uranium; entrapment of uraniferous waters; precipitation of uranium; connection of structural features and geologic history with localization of mineralization. Authors suggest that "asphaltic residue" functions as a precipitating agent in ore-forming processes so that the "residue" is directly responsible for distribution of uranium ore through precipitation of the uranium from waters entrapped in a closed continental basin.

Subject Index

This index is organized into the following main categories:

- Stratigraphy
- Structural Geology
- Ore Deposits (in general)
- Morrison Deposits (excluding genesis)
- Todilto Deposits (including genesis)
- Dakota Deposits (including genesis)
- Genesis of Deposits (in general)
- Genesis of Sources of Uranium in Morrison
- Geologic Maps
- Reference Sources

Several of these categories include subheadings, the most complete listings appearing under stratigraphic units comprising chief hosts of uranium deposits.

Although some of the reports appearing under Structural Geology do not specifically pertain to features within the Grants region, they have been included. For example, the evolution of the drainage of the Colorado River or studies of the younger volcanics may not seem relevant; nonetheless, both have had a significant effect on recent uplift of the Grants region.

Numbers to left of author's name refer to citations listed in bibliography.

STRATIGRAPHY

Includes publications with stratigraphic information pertinent to the general area of Grants uranium region, immediately adjacent areas, or major parts of the region. Reports giving stratigraphic information on such localized areas as specific deposits or properties are ordinarily grouped in the various ore-deposit categories. Where appropriate, studies and reports are cross-indexed. The term *stratigraphy* is here used broadly; relevant studies of petrology and sedimentational history are included. Also, studies of certain structural features, ordinarily handled as peculiar to Todilto Limestone, are included. Subheadings consist of geologic units listed from oldest to youngest.

110 Gruner and Gardiner, 1951
121 Harshbarger and others, 1957
122 Harshbarger and others, 1958
127 Hilpert, 1963
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131 Hilpert and Moench, 1960
158 Kelley and others, 1968
162 Kerr and Hamilton, 1954
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172 Konigsmark, 1958
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122 Harshbarger and others, 1958

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45 Craig and others, 1955
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34 Cadigan, 1959
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45 Craig and others, 1955
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27 Bozanic, 1955
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271 Smith, 1954

STRUCTURAL GEOLOGY

Includes studies and reports with structural information pertinent to the general area of Grants uranium region, immediately adjacent areas, or major parts of the Belt. Reports giving structural information on localized areas such as specific deposits or properties are ordinarily grouped in the ore-deposit categories. Where appropriate, studies and reports are cross-indexed.

15 Baker and Ridley, 1970
17 Barnes and Arnold, 1951
31 Bucher, 1953
55 Duschatko, 1953
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190 McKee, E. D., and McKee, E. H., 1972
191 McKee, E. D., and others, 1956
192 McKee, E. D., and others, 1967
193 McKee, E. H., and Anderson, 1971
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279 Smith, 1970
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311 Wengerd, 1959
312 Whelan, 1952
317 Young and Ealy, 1956
319 Zitting and others, 1957

ORE DEPOSITS (in general)

Includes studies and reports giving following information about general ore deposits of Grants uranium region: compilations of locality data,

compilations of sketch descriptions (geologic and other) of mineralized localities, descriptions of exploration methods and techniques, descriptions of mining methods and techniques, histories of the uranium industry.

1 Abbiss, 1963
6 Anderson, 1955
7 Anderson, 1957
16 Ballmer, 1963
37 Cannon, 1960
52 Dinwiddie, 1963
67 Fitch, 1971
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96 Grundy and Meehan, 1963
125 Heinrich, 1958
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143 John and West, 1963
144 Johnston, 1963
153 Kelley, 1963a
179 Linton, 1963
183 Lovering, 1956
187 Matthews, 1963
200 Melancon, 1963
280 Smith, M. C., Jr., 1967
300 USAEC, 1966
301 USAEC, 1970
301½ New Mexico Bureau Mines Min. Resources, 1965

MORRISON DEPOSITS (excluding genesis)

Includes reports giving significant geologic information about individual Morrison ore deposits of Grants uranium region.

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158 Kelley and others, 1968
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229 Perry, 1961
243 Rosenzweig, 1961
282 Squyres, 1970
315 Wylie, 1963

TODILTO DEPOSITS (including genesis)

Includes reports giving geologic information about deposits in Todilto Limestone, including those that overlap into adjacent strata of underlying and overlying formations, Entrada Sandstone and Summerville Formation, respectively.

8 Anderson and Kirkland, 1960
21 Bell, 1956

24 Bell, 1963
25 Berglof and Wampler, 1965
33 Butler and Schnabel, 1956
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56 Ellsworth and Mirsky, 1952
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75 Gabelman, 1956c
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131 Hilpert and Moench, 1960
142 Jobin, 1962
158 Kelley and others, 1968
160 Kerr and Dahl, 1953
161 Kerr and Hamilton, 1953
163 Kerr and Wilcox, 1963
169 Kittle and others, 1967
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176 Laverty and others, 1963
194 McKelvey, 1955
195 McKelvey and others, 1955
197 McLaughlin, 1963
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299 Truesdell and Weeks, 1960
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314 Wright, 1955

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89 Granger, 1963b
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118 Gruner and others, 1954
128 Hilpert, 1969
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169 Kittle and others, 1967
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202 Mirsky, 1953
271 Smith, 1954
317 Young and Ealy, 1956

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Includes studies of a background nature, therefore applicable in general to investigations of uranium deposits of Grants uranium region. Citations are cross-indexed to appropriate categories where they contain information of more specific interest.

2 Abdel-Gawad and Kerr, 1961
3 Adler, 1963
21 Bell, 1956
22 Bell, 1960a
23 Bell, 1960b
24 Bell, 1963
28 Breger and Deul, 1959
42 Coleman and Delavaux, 1957
57 Erickson and others, 1954
59 Finch, 1964
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114 Gruner and Smith, 1955a
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118 Gruner and others, 1954
139 Jensen, 1958
140 Jensen, 1963
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237 Reinhardt, 1952
244 Rosenzweig and others, 1954
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286 Stokes, 1961
302 Vine, 1962
303 Vine and others, 1958
306 Weeks, 1956
307 Weeks and Garrels, 1959
308 Weeks and Thompson, 1954
313 Woodmansee, 1958

GENESIS OF SOURCES OF URANIUM IN MORRISON

Includes reports giving significant consideration to genesis of groups of Morrison deposits of Grants uranium region. Those reports giving consideration to genesis of individual deposits or deposits of a particular property are ordinarily included under "Ore deposits in Morrison Formation." Studies are further grouped in this category according to the particular original source of uranium favored by an author in consideration of genesis. If considerations did not include the source of the uranium or an author concluded that the source could be any of several possibilities, the study is included under "unspecified source."

SEDIMENTS OF HOST FORMATIONS, SOURCE TERRAIN OF HOST SEDIMENTS, OR BOTH

SEDIMENTS OF HOST FORMATION

SOURCE TERRAIN OF HOST SEDIMENTS

UNSPECIFIED

HYDROTHERMAL SOLUTIONS

GEOLOGIC MAPS

Includes maps published separately, such as the U.S. Geological Survey quadrangle maps and maps published under separate titles in guidebooks.