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National Uranium Resource Evaluation

TONOPAH QUADRANGLE NEVADA

Bendix Field Engineering Corporation
Grand Junction, Colorado

Issue Date
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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
Grand Junction Area Office, Colorado

MASTER

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NATIONAL URANIUM RESOURCE EVALUATION
TONOPAH QUADRANGLE
NEVADA

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Grand Junction Operations
Grand Junction, Colorado 81502

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION AREA OFFICE
UNDER CONTRACT NO. DE-AC07-76GJ01664

This is the final version of the subject-quadrangle evaluation report to be placed on open file. This report has not been edited. In some instances, reductions in the size of favorable areas on Plate 1 are not reflected in the text.

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INTRODUCTION

PURPOSE

The Tonopah Quadrangle, Nevada (Figure 1), was evaluated to a depth of 1500 m (5,000 ft) to identify geologic environments and delineate areas that exhibit characteristics favorable for uranium deposits. Favorable environments are those that could contain at least 100 tons of U_3O_8 in rocks having an average grade of at least 0.01 percent U_3O_8. Selection of a favorable environment is based on the similarity of its geologic characteristics to the National Uranium Resource Evaluation (NURE) recognition criteria described by Mickle and Mathews (eds., 1978). The study was conducted by the Reno Field Office of Bendix Field Engineering Corporation (BFEC) for the NURE program, managed by the Grand Junction Office of the U.S. Department of Energy (DOE).

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SCOPE

The Tonopah Quadrangle project began with literature research and work-plan formulation on May 1, 1980; these activities required 0.3 man-years to complete. The succeeding field study and data compilation and evaluation required 1.0 man-years and began on July 1, 1980. Report preparation began January 1, 1981, and required 0.3 man-years to complete.

PROCEDURES

The Tonopah Quadrangle evaluation consisted of the following activities:

1. Surface study
2. Aerial radiometric followup
3. Hydrogeochemical and stream-sediment reconnaissance followup
4. Subsurface study
5. Sampling and analyses

Surface Study

The surface study consisted of reconnaissance of the accessible areas of the Tonopah Quadrangle and detailed investigation of selected geologic

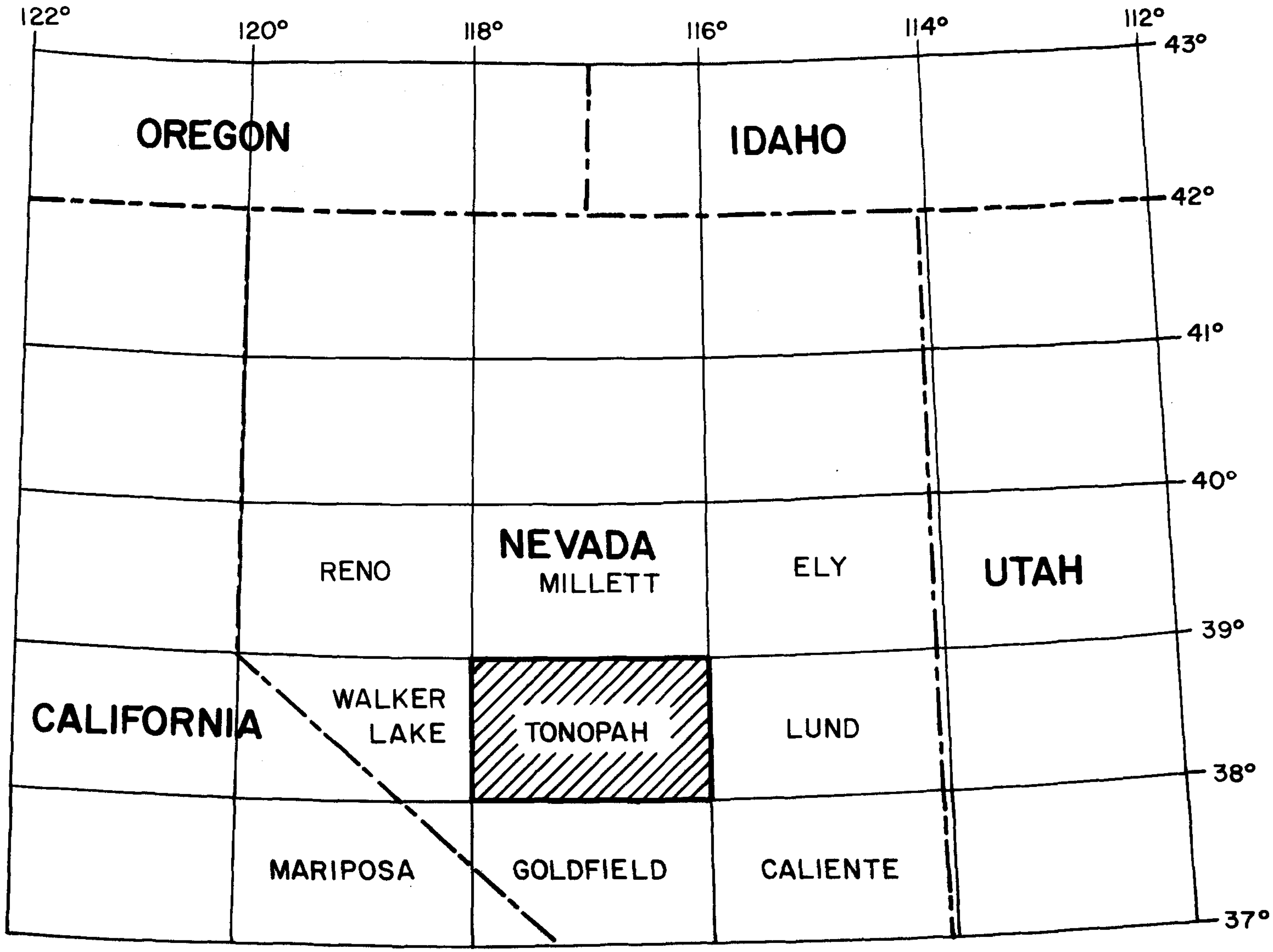

Figure 1. Tonopah Quadrangle location map.

environments. Known and newly discovered uranium occurrences were studied and sampled (Plate 2). The data from surface studies are recorded in Appendices A, B-1, B-2, B-3, C, D, E, and F.

The surface reconnaissance included scintillometer (Mt. Sopris SC-132) and field gamma-ray spectrometer (GR-310) surveying, identification and sampling of major rock types, and sampling of mineralized environments. Scintillometer surveying was carried out utilizing road and foot traverses, whereas the spectrometer survey was conducted at selected sample locations. Sampling of major rock types was done concurrently with radiometric surveying.

Detailed surface investigations were conducted in the immediate vicinity of uranium occurrences. These investigations included rock sampling, localized geologic mapping, scintillometer and gamma-ray spectrometer surveying, and in some instances, secondary followup sampling.

Aerial Radiometric Followup Study

The aerial radiometric survey of the Tonopah Quadrangle was completed prior to this study by Geodata International, Inc. (1979). Followup of this survey consisted of geologic reconnaissance, surface scintillometer surveying, and rock sampling in the vicinity of indicated anomalies (Plate 3); this followup was carried out concurrently with surface investigations of the same areas.

HSSR Followup Study

The Hydrogeochemical and Stream Sediment Reconnaissance report was completed by Lawrence Livermore Laboratory (LLL) in 1979. Followup of this survey consisted of geologic reconnaissance, surface scintillometer surveying, and rock sampling in the vicinity of indicated anomalies (Plate 4); this followup was carried out concurrently with surface investigation of the areas.

Subsurface Study

Subsurface data were obtained from the U.S. Geological Survey (USGS) and U.S. Atomic Energy Commission (AEC), as well as from confidential information supplied by several private companies. This information was used to confirm minimum grade levels in both areas designated as favorable in the Tonopah Quadrangle. Subsurface data were also used to substantiate unfavorability of occurrences for the Brunton Pass, Stewart Valley, Monte Cristo Range, northern Ralston Valley, Stone Cabin Valley, and Hot Creek Range areas.

Sampling and Analyses

Initial sampling was begun in 1978 by Carl Welch; he collected 69 rock samples, primarily during uranium-occurrence studies (Plate 2). Fluorimetric-uranium and 29-element emission spectrographic analyses were run on these samples; 29 samples were analyzed by Rocky Mountain Geochemical of Sparks, Nevada, and TSL Laboratories, Inc., in Opportunity, Washington, analyzed the remaining 40 samples. One rock was submitted to the BFEC laboratory in Grand Junction, Colorado.

Rock sampling resumed in 1980 with the collection of an additional 187 samples (Plate 5). Fluorimetric-uranium and 34-element emission spectrographic analyses were run on all rock samples by the BFEC laboratory in Grand Junction, Colorado. Selected rock samples were sent to the BFEC laboratory for petrographic and rapid-rock analyses and for gamma-ray spectroscopic determination of equivalent uranium, equivalent thorium, and potassium.

Equivalent thorium-to-chemical uranium ratios are used as indicators of uranium enrichment or depletion in this report. Equivalent-thorium values are based upon gamma-ray spectroscopic measurements of the daughter products of thorium decay. Because of the relative chemical immobility of thorium, equivalent-thorium values are assumed to accurately represent the original thorium content of the rocks examined. Chemical-uranium values, adjusted from U_3O_8 assays of rock samples, accurately reflect the present uranium content of these samples. In contrast, equivalent uranium values, obtained from gamma-ray spectroscopic measurements of uranium daughter products, reflect the daughter products content only and may not accurately represent the amount of uranium, a more mobile element, present.

PHYSIOGRAPHY AND ACCESSIBILITY

The Tonopah Quadrangle is within the Great Basin and includes portions or all of 12 mountain ranges and 10 basins. Elevations are from 1360 m at Columbus Salt Marsh to 3642 m at Mount Jefferson. Large areas of several ranges exceed 2700 m; valley floors typically exceed 1500 m. The climate is semiarid to arid for the quadrangle except in the higher portions of the higher mountain ranges.

All valleys within the quadrangle are accessible by road or jeep trail, as are most of the lower mountainous areas. The higher mountainous areas are generally accessible only by foot, particularly in the Hot Creek, Monitor, Toiyabe, and Toquima Ranges.

GEOLOGIC SETTING

The Tonopah Quadrangle, Nevada, is between lat 38°00'00"N. and 39°00'00"N. and long 116°00'00"W. and 118°00'00"W. (Figure 1). The entire quadrangle is within the Basin and Range physiographic province and is characterized by north-northeast-trending, block-faulted horst mountains separated by deep graben basins.

Rock Type

The oldest rocks in the quadrangle are metamorphosed lower Precambrian claystone, siltstone, limestone, and dolomite at Lone Mountain in the southwestern portion of the quadrangle (Figure 2; Albers and Stewart, 1962, 1972). Paleozoic marine carbonate and clastic sedimentary rocks, locally

ERA	SYSTEM	SERIES	MAP UNIT	LITHOLOGY	DESCRIPTION
Cenozoic	Quaternary	Holocene	Qs, Qb		Alluvium fan deposits, stream gravel, dune sands, playa lake deposits, basalt flows and cinder cones.
		Pleistocene			Older gravel, lake beds, terrace deposits, landslide deposits, basaltic rocks.
	Tertiary	Pliocene	Timv		Andesite, basalts, quartz, latite flows, plugs, and dikes, dacite porphyry.
		Miocene			Rhyolite to quartz latite ash flow tuffs, dacite, rhyolite intrussions, tuffaceous shale, sandstone, diatomite.
		Oligocene	Tfv, Ts		Rhyolitic ash flow tuffs, dacitic to andesitic lava flows, welded tuffs, ash flow tuffs, tuffaceous and clastic sedimentary rocks.
Mesozoic	Cretaceous				Sandstone, shale, conglomerate.
	Jurassic		Msv		Conglomerate, sandstone, silty limestone, siltstone.
	Triassic				Limestone, dolomite, shale, sandstone, conglomerate, and felsic volcanic rocks.
Paleozoic	Permian				Altered andesitic flows, breccias, chert conglomerate, shale, and limestone.
	Pennsylvanian				Sandy conglomeratic limestone.
	Devonian		Ps		Limestone with some shale.
	Silurian				Limestone, dolomite, and shale.
	Ordovician				Dolomite, quartzite, chert, siltstone, and volcanic rock, black shale.
Precambrian			p€s		Bedded limestone, dolomite, dark quartzite, and siltstone.

Figure 2. Generalized stratigraphic column.

attaining an exposed thickness of more than 1000 m, are in most mountainous portions of the quadrangle. These Precambrian and Paleozoic sedimentary rocks were apparently deposited in moderate to shallow water depths near the cratonic margin. Mesozoic (primarily Triassic) volcanic and volcaniclastic sedimentary rocks, intercalated with shallow-marine carbonate and clastic sedimentary rocks, overlie the Paleozoic rocks over much of the western third of the quadrangle (Albers and Stewart, 1972; Ross, 1961).

Middle Mesozoic to lower Tertiary plutonic rocks of granitic to gabbroic composition intrude all older rock types of the region. Within the Tonopah Quadrangle, mafic to intermediate plutons are restricted to small exposures at Lone Mountain and the Paradise Range. Mesozoic felsic plutonic rocks are much more common and are exposed at Lone Mountain and in the Cedar Hills and the Monte Cristo, Paradise, Toquima, Shoshone, Toiyabe, and San Antonio Ranges (Plate 12). These rocks are not found in the western third of the quadrangle.

Tertiary felsic volcanic rocks are the most common rocks in the Tonopah Quadrangle and are widely exposed in all mountain ranges. The majority of these felsic volcanic rocks are Oligocene and Miocene ash-flow tuffs of rhyolitic quartz latitic composition. These tuffs apparently were erupted from a number of inferred vents within the Tonopah Quadrangle. Late Tertiary volcaniclastic and lacustrine sedimentary rocks are locally interbedded with the felsic volcanic rocks over much of the quadrangle and are locally overlain by later rhyolite flows and domes.

Structure

Both Tertiary and Quaternary intermediate and mafic volcanics, predominantly of flow origin, are present throughout the Tonopah Quadrangle. The Quaternary volcanic rocks are locally intercalated with and overlain by Quaternary alluvial, landslide, lacustrine, and playa sediments. No uranium occurrences are known in the Tertiary and Quaternary intermediate and mafic volcanic rocks or associated Quaternary sediments within the quadrangle.

Throughout the quadrangle, the Precambrian and Paleozoic rocks have been folded into approximately north-trending open folds. These folded sediments and at least some of the overlying Mesozoic volcanic and sedimentary rocks are cut by thrust faults that predate Mesozoic to lower Tertiary plutonic rocks. Subsequent minor low-angle faulting occurred locally, adjacent to intrusive margins; and minor folding, likely due to compaction and soft-sediment slumping, has locally deformed the Tertiary Siebert Formation. All rock types in the quadrangle are cut by late Tertiary and Quaternary basin-and-range high-angle faults.

The western third of the Tonopah Quadrangle lies within a transitional zone of disturbed structure between the Sierra Nevada province to the west and the more typical Basin and Range Province in the eastern two-thirds of the quadrangle (Bonham and Garside, 1979; Ekren and others, 1980; Ferguson and Muller, 1949). This transition zone is typified by a parallel and subparallel right-lateral strike-slip fault zone, which extends southward into the northwest corner of the quadrangle.

Metamorphism

Regional metamorphism of variable intensity has affected the Precambrian and Paleozoic sedimentary and the lower Mesozoic volcanic and sedimentary rocks of the Tonopah Quadrangle. Metamorphic intensity ranged locally from essentially unmetamorphosed to greenschist facies; Precambrian rocks are the most pervasively metamorphosed rocks in the quadrangle (Albers and Stewart, 1962).

Contact metamorphism is prevalent around the margins of granitic plutons and is especially pronounced in carbonate rocks, which are metamorphosed to calc-silicate scarns. Where the plutons intrude argillaceous sediments, hornfels have developed in inner aureole zones.

Ore Deposits

A number of different types of ore deposits are present in the Tonopah Quadrangle. Notable among these are silver vein deposits of the Reveille and Tonopah districts (Albers and Klinhampl, 1970; Basin and Laney, 1918; Bonham and Garside, 1979; Bonham and others, 1972; Eakle, 1912; Kral, 1951; and Spurr, 1905), gold vein deposits of the Manhattan, Round Mountain, and Belmont districts, bedded barite deposits of Northumberland Canyon (Shawe and others, 1967), porphyry molybdenum deposits of the San Antonio Mountains (Davis and others, 1971; Kral, 1951), playa potash and borate deposits of Columbus Salt Marsh (Hicks, 1915), the turquoise deposits at Royston Hills and Lone Mountain (Morrissey, 1968), and brucite deposits in the Paradise Range (Callaghan, 1933). Numerous other small precious- and base-metal deposits are associated with the Paleozoic sedimentary and Mesozoic plutonic rocks of the quadrangle (Ferguson, 1916, 1927, 1933).

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

Two areas in the Tonopah Quadrangle have environments favorable for uranium deposits (Plate 1). Area A (the Big Smoky Valley west of Tonopah) is favorable for hydroallogenic uranium deposits (Class 540; Pilcher, 1978). Area B (the Toquima and Belmont granitic plutons) is favorable for authigenic deposits (Class 360; Mathews, 1978).

AREA FAVORABLE FOR HYDROALLOGENIC DEPOSITS
Miocene Lacustrine Sediments of the Big Smoky Valley west of Tonopah

Characteristics of Host Rocks. Sedimentary rocks of the Miocene Siebert Formation in the Big Smoky Valley contain environments favorable for hydroallogenic uranium deposits (Class 540; Pilcher, 1978). The Siebert Formation, originally called the Siebert Tuff (Spurr, 1905), contains a wide variety of sedimentary and volcanic rocks (Bonham and Garside, 1979). Sedimentary rock types include conglomerates, sandstones, and siltstones of fluvial origin and lacustrine claystones, shales, diatomites, and limestones. The coarser clastic sediments are most common near the base of the Siebert and along the flanks of the San Antonio and Lone Mountain horsts. Finer grained sediments are much more common basinward in the Big Smoky and Montezuma (between Tonopah and Lone Mountain) Valleys. Most of the clastic sediments within the Siebert Formation contain tuffaceous material (Bonham and Garside, 1979).

Volcanic rock types within the Siebert Formation are predominantly felsic lapillistones and tuff breccias of pyroclastic origin. These pyroclastic rocks are commonly interbedded with the Siebert sediments throughout the formation. Much less common and limited to the upper part of the Siebert Formation are trachyandesite flows; dikes of similar composition locally intrude underlying portions of the formation.

The type locality of the Siebert Formation is the exposed section of sedimentary and volcanic rocks on Siebert Mountain just southwest of Tonopah (Bonham and Garside, 1979). At the type locality, the Siebert is approximately 180 m thick but may be considerably thicker basinward (Erwin, 1968). The Siebert overlies with angular unconformity earlier Miocene pyroclastic and flow rocks and is intruded and unconformably overlain by later Miocene volcanic plugs and flows, respectively. The age of the Siebert has been determined as 13 to 17 m.y. years by radiometric age dating. This age agrees with a Barstovian age indicated by fossil assemblages, which include mammal, fish, gastropod, ostracod, and algal fossils (Bonham and Garside, 1979).

Uranium Occurrences in Siebert Formation Sediments. The Foster, Bobby Jack (plus Jeep, Lincoln, and Roan Claims), and Silver Queen (plus Garibaldi and Rich and Rare Claims) uranium occurrences are hosted by lacustrine sediments of the Siebert Formation (Plate 2; Appendix C). Each of these occurrence groups actually consists of a number of closely spaced small uranium-enriched zones. The three occurrence groups lie along a north-northwesterly trend of anomalously high radioactivity that is approximately 13 km long and more than 1 km wide (Davis and Hetland, 1956). This trend is approximately parallel to the western boundary of the San Antonio Mountains horst. Individual occurrences along the trend appear related to approximately north-trending minor faults and fractures but exhibit considerable stratigraphic control locally (Garside, 1973). Although lacustrine claystones and shales are the predominant host uranium, both fluvial sandstone and tuffs are locally enriched in uranium.

The Silver Queen occurrence group is the largest and best exposed. Uranium mineralization at this locality took place primarily in phosphatic claystones and shales and in strongly silicified, locally brecciated, fine-grained sediments hereafter referred to as opalite breccia. Both the claystone and shales typically contain both tuffaceous and diatomaceous material. The opalite beds are extremely fine grained and range from massive to thinly laminated. Those seen by the authors vary in thickness from a few centimeters to several meters and appear to be laterally discontinuous. This variation suggests that these opalites are lenses intercalated with the thicker surrounding lacustrine beds. Upper and lower contacts between the opalite and the bounding claystones and shales appear gradational; whether this represents primary depositional facies changes or limits of subsequent silicification is unknown. The opalite breccias are rarely present within areas of opalite beds and appear to have been formed in moundlike or pipelike masses. These masses resemble paleo-hot-spring mounds, in lake sediments, seen by the authors at the McDermitt Mercury Mine in northern Nevada.

Although lacustrine sediments are the primary host rocks at the Silver Queen occurrence, uranium concentrations here also occur in sandstone, conglomerate, and felsic tuff. Uranium enrichment in these rocks is limited to very small areas near contacts with the lake sediments. Enrichment appears closely related to the same processes that mineralize the lacustrine beds. At the Foster and Bobby Jack occurrences, sandstones are intercalated with mineralized claystones and shales and are themselves mineralized to a lesser extent. Silicification is locally noticeable at both these occurrences, but no true opalite or opalite breccia was seen by the authors. No mineralized tuffs were noted at either the Foster or the Bobby Jack occurrences.

Several types of alteration have been noted in the Siebert Formation, particularly in the lake sediments. Silicification of these sediments is, of coarse, widespread, but whether this silicification is due to primary deposition or subsequent alteration is unknown. Petrologic investigation indicates volcanic-ash material originally present in these sediments has been completely devitrified and altered to clay minerals, zeolites, ferruginous clays, limonite as veinlets and small diffuse patches, and hematite (Appendix F). Oxidation is common in surface exposures of both the lacustrine and fluvial sediments, and the most radioactive zones appear to be in oxidized hosts. At both the Silver Queen and Foster prospects, uranium mineralization appears related to oxidized claystone beds containing small (3 mm in diameter) oxidized spheriods that resemble oxidized iron sulfide nodules. Pyrite has been reported in unoxidized mineralized sediments in the subsurface at the Silver Queen (Garside, 1973), which indicates prior reduction of these sediments.

The sediments of the Siebert Formation occurrences are most commonly white to light gray, where unaltered. Where altered, the sediments are most commonly yellow to reddish brown and display oxidation bands. Portions of the matrix of the opalite breccia are reddish brown, even where this rock appears unoxidized. Fracture surfaces in the oxidized sediments are, in rare instances, coated with a black film which may be a manganese oxide.

With the exception of pyrite noted from subsurface samples, no reductants have been identified at these occurrences. Uranium appears to have been concentrated by inclusion, within cryptocrystalline apatite (collophanite) of the claystones and shales, and within the opaline silica of the opalite and opalite breccia. Uranium appears to be adsorbed on clay, zeolite, and iron oxide minerals. Except for a minor occurrence of autunite in tuff at the Bobby Jack occurrence (Garside, 1973), no uranium minerals are reported at the Big Smoky Valley occurrences.

The maximum uranium content found by us in the Big Smoky Valley occurrences is 1,820 ppm (U_3O_8), in a sample (MER-061) of gray shale from the southern portion of the Foster occurrence (Table 1; Appendix B-1; Appendix C). A U_3O_8 value of 1,307 ppm from a sample (MER-067) of oxidized silty claystone is the maximum assay from the Bobby Jack occurrence (collected at the Jeep and Lincoln Claims portion). The maximum U_3O_8 assay at the Silver Queen group is 1,160 ppm in a sample of oxidized white claystone (MER-072). Mean assays from mineralized samples taken at the Foster, Bobby Jack, and Silver Queen occurrences are 587, 484, and 511 ppm U_3O_8, respectively. Lowest U_3O_8 contents in unmineralized rocks from the Foster, Bobby Jack, and Silver Queen are 2, 3, and 7 ppm, respectively.

Ratios of laboratory gamma-ray spectrographic equivalent U_3O_8 values to U_3O_8 assays from selected samples range with two exceptions from 0.47 to 1.00, showing consistent uranium disequilibrium in favor of chemical uranium (Table 1). This may be due to either (1) such recent deposition of uranium that it has not yet produced sufficient daughter elements to be in secular equilibrium or (2) a leaching of daughter products. The authors believe the first circumstance to be most likely; such a circumstance may indicate supergene concentration of uranium in oxidized surface rocks during weathering. The two eU_3O_8 to cU_3O_8 ratios that exceed unity are 6.91 and 3.93 (Table 1). These high ratios indicate strong depletion of uranium, likely due to leaching during weathering.

The anomalous uranium correlates closely with high contents of calcium and phosphorus, which are constituent elements of apatite (Plate 9, Appendix B-1). Only one sample containing more than 50 ppm U_3O_8, an opalite breccia from the Silver Queen occurrence (MER-079) containing 133 ppm U_3O_8, has low contents of calcium and phosphorus. In this sample, uranium is likely held in opaline silica rather than cryptocrystalline apatite. Both molybdenum and zirconium show order-of-magnitude differences between high and low in Silver Queen and Foster Group samples, but these variations are not correlative with changes in uranium content (Appendix B-1, Appendix C). Anomalous values for arsenic were noted in several uranium-mineralized samples from the Silver Queen and Bobby Jack prospects, but other mineralized samples contained much lower arsenic contents. It does not appear that variations in arsenic and uranium contents are directly related (Appendix B-1, Appendix C).

The presence of uranium at the Big Smoky Valley occurrences may be detected by aerial radiometric surveying. The Foster and Bobby Jack occurrences lie directly beneath a line flown during the aerial radiometric survey of the Tonopah Quadrangle, and a bismuth-214 (uranium daughter product) anomaly is shown in their vicinity (Geodata International, 1979). The Silver Queen workings lie between lines flown in this survey.

As there is no surface water nor any water wells within that portion of the Big Smoky Valley encompassed in Area A, no ground-water information is available. No stream-sediment anomalies were noted in or near Area A (Qualheim, 1979).

Although it is not within favorable Area A, one other uranium occurrence should be mentioned in connection with the Siebert Formation occurrences. This occurrence is the Can't Miss prospect located at the south end of Cedar Mountain about 38 km (23 mi) northwest of the Foster occurrence (Plate 2, Appendix C). The Can't Miss occurrence is hosted by upper Tertiary fluvial and lacustrine sediments and an underlying Miocene ash-flow tuff. These sediments strongly resemble lacustrine and fluvial sediments exposed along the west side of Big Smoky Valley; they are mapped as Esmeralda Formation (Albers and Stewart, 1972) but appear to the authors to be identical to the Siebert Formation. The rocks along the west side of Big Smoky Valley and on Cedar Mountain overlie the Fraction Breccia (Albers and Stewart, 1972), which also lies directly beneath the Siebert Formation west of Tonopah (Bonham and Garside, 1979). Uranium mineralization at the Can't Miss occurs in oxidized sandstones (interbedded with lacustrine shales) and brecciated and silicified Fraction ash-flow tuff (Appendix C). The maximum U_3O_8 assays in sandstone

TABLE 1. GAMMA SPECTROSCOPY ANALYSIS OF SELECTED ROCKS FOR FAVORABLE AREA A*

Sample # (MER-)	Uranium Occurrence	Rock Type+	CPS**	Chemical U_3O_8 (ppm)	Calculated cU (ppm)	Equivalent U (ppm)	Equivalent Th (ppm)	eTh/eU	eTh/cU	eU/cU
058	Foster Group	cs	2500	560	475	376	30	.08	.06	.79
059	Foster Group	cs	900	243	206	---	---	---	---	---
060	Foster Group	sh	140	3	2.5	---	---	---	---	---
061	Foster Group	sh	1800	1820	1543	995	407	.41	.26	.64
092	Foster Group	lbs	1000	273	232	245	14	.06	.06	1.06
093	Foster Group	lbs	85	2	1.7	2	3	1.5	1.76	1.18
094	Foster Group	lbs	1700	553	469	---	---	---	---	---
095	Foster Group	lbs	2500	72	61	283	13	.05	.21	4.64
062	Bobby Jack	sh	900	560	475	313	87	.28	.18	.66
063	Bobby Jack	sts/cs	1000	560	475	263	119	.45	.25	.55
064	Bobby Jack	ss	1100	103	87	---	---	---	---	---
065	Bobby Jack	ss	1400	289	245	---	---	---	---	---
066	Bobby Jack	ss	1500	184	156	---	---	---	---	---
067	Bobby Jack	cs	3000	1307	1108	774	102	.13	.09	.70
068	Bobby Jack	ss/cs	3750	467	396	386	82	.21	.21	1.0
069	Bobby Jack	ss	1700	401	340	---	---	---	---	---
070	Silver Queen	lbs	4500	45	38	311	1260	4.1	33.16	8.18
071	Silver Queen	lbs	2000	499	423	384	100	.26	.24	.91
072	Silver Queen	lbs	11200	1160	984	1147	374	.33	.38	1.17
073	Silver Queen	lbs	6600	940	797	---	---	---	---	---
074	Silver Queen	lbs	225	15	12.7	---	---	---	---	---
075	Silver Queen	lbs	2700	500	424	425	531	1.2	1.25	1
076	Silver Queen	lbs	200	7	5.9	---	---	---	---	---
077	Silver Queen	lbs	260	20	17	---	---	---	---	---
078	Silver Queen	lbs	1000	283	240	---	---	---	---	---
079	Silver Queen	lbs	800	133	113	105	5	.05	.04	.93
080	Silver Queen	lbs	2500	10	8.5	---	---	---	---	---
091	Silver Queen	lbs	2500	60	51	---	---	---	---	---

*Gamma Spectroscopy analysis run by BFEC personnel in Grand Junction, Colorado Office.
+See Appendix B-3. Table of Abbreviations.
**Mt. Sopris Scintillometer SC-132.

and tuff at the Can't Miss are 324 and 228 ppm, respectively. Chemical analysis and petrology indicate uranium is held in the cryptocrystalline apatite structure (Appendix B-1; Appendix F). However, drilling at this prospect failed to encounter uranium in grades and tonnages of economic interest (Joe L. Johnson, pers. comm., 1980). If these sediments are of provenance and depositional history similar to those of sediments along the west side of Big Smoky Valley, it is likely that environments favorable for uranium deposits may be beneath the Quaternary alluvial cover continuously across Big Smoky Valley. Due to the lack of subsurface data, the depth, lithologies, and distribution of the postulated Siebert Formation extension beneath the valley is unknown.

Summary

The uranium occurrences of the Big Smoky Valley west of Tonopah are in a graben basin of the Basin and Range Province. The occurrences seem to be along minor faults and fractures, which approximately parallel the normal fault(s) bounding the east side of the graben. At individual occurrences, uranium mineralization appears to be predominately in tuffaceous lacustrine claystones and shales. Minor uranium enrichment is also in interbedded fluvial sandstones and ash-flow tuffs. The shape of the deposits is tabular to lenticular and apparently stratiform in most instances. Silicification, argillization, and zeolitization are common in these deposits, and pyritization is known from the subsurface. Uraniferous opal is apparently present at the Silver Queen occurrence (Davis and Hetland, 1956), and molybdenum, although not directly correlative with uranium content, is enriched in some Silver Queen samples. Nearly all equivalent thorium-to-chemical U_3O_8 ratios for these occurrences are less than unity (Table 1). All of the aforementioned characteristics are consistent with the recognition criteria for hydroallogenic uranium occurrences (Class 540; Pilcher, 1978). Based on these occurrences, Area A in the Big Smoky Valley is considered favorable for hydroallogenic uranium deposits.

Speculations on the Origin of the Big Smoky Valley Occurrences

Two theories of origin have been suggested for the Big Smoky Valley uranium occurrences. Davis and Hetland (1956) favor a hydrothermal origin, whereas Garside (1973) suggests a ground-water ash-leach mode of origin. Garside points out the absence of typical hydrothermal features and mineralogy as evidence against a hydrothermal origin for these deposits. However, a simple ash-leach theory does not explain the apparent localization of the occurrences along faults and fractures and the sinterlike opalite breccia and cryptocrystalline apatite. In addition, these deposits lack the abundance of calcium uranyl phosphate minerals (particularly autunite) present in other Basin and Range hydroallogenic occurrences, such as the Tick Canyon Mine, which are thought to be of ash-leach origin (Hurley and others, 1980).

The authors believe that these occurrences were formed by a hot-spring system that included both shallow hydrothermal (geothermal) and ash-leach processes. The similarity between the opalite lenses, opalite breccia, and lacustrine sediments at the Silver Queen prospect and the McDermitt Mine are striking. The McDermitt mercury deposit is believed to have formed in a hot-spring environment along a fault system; this fault system deposited apronlike lenses of siliceous sinter within a sequence of concurrently deposited tuffaceous lake sediments (Roper, 1976). A similar origin is suggested for the Opalite and Bretz mercury deposits, which are also uranium occurrences (Roper, 1976; Rytuba and Glanzman, 1978). Such a hot spring-lacustrine environment would seem to explain the interbedded opalite lenses, opalite breccia, and extensive devitrification and argillization of the sediments at the Silver Queen occurrence. It would also explain the localization of the Big Smoky Valley occurrences along fault and fracture systems. The uranium in these occurrences may have originated from a deep hydrothermal source or from ash-leach of tuffaceous sediments and tuffs by circulating geothermal ground waters. The lack of typical hydrothermal vein characteristics leads the authors to favor the latter source alternative.

A hot spring emanation into cooler lake waters may also explain the presence of uraniferous apatite in the Big Smoky Valley occurrences. Krauskopf (1967) describes two mechanisms for the formation of marine phosphorites; these mechanisms might also be applicable in a hot spring-lacustrine environment. In one case, upwelling waters rich in calcium and phosphate lost carbon dioxide due to decreasing pressure and consumption during plant photosynthesis; as a result, calcium phosphate minerals are inorganically precipitated. In the second instance, abundant aquatic life stimulated by upwelling warm, phosphate-rich waters precipitates calcium phosphates organically as skeletal material. The warm circulating waters of the postulated geothermal system may have been enriched in phosphates during migration through the Siebert sediments; the sediments locally contain not only vertebrate and invertebrate fossils (Bonham and Garside, 1979) but also include tuffs at the base of Siebert Mountain made up entirely of diatoms (Spurr, 1905b, p. 69). The presence of limestone beds near the Bobby Jack occurrence attests to calcium enrichment within these waters. The action of the abundant aquatic life, commonly associated with the present hot springs of the region and recorded in the Siebert fossil record, may have led to the inorganic and/or organic precipitation of the calcium phosphate apatite. Where uranium was in the geothermal waters, it became incorporated in the precipitating collophane. The irregular distribution of the mineralized zones may be explained by the irregular occurrence of hot springs along faults and fractures, periods of nondeposition of phosphatic beds, and interruptions in hot spring activity and uranium supply. Perplexing features, such as beds that are mineralized on only one side of a fracture system (Garside, 1973), may be explained by current drift of the uranium-bearing hot waters.

The rare autunite and the disequilibrium in favor of chemical uranium likely seem due to recent supergene enrichment of uranium in near-surface environments during weathering. If these deposits are due to epigenetic hydrothermal or ash-leach processes, the disequilibrium in favor of chemical uranium may indicate a very recent age of primary mineralization for the Big Smoky Valley occurrences.

AREA FAVORABLE FOR AUTHIGENIC DEPOSITS

Granitic Rocks of the Toquima and Belmont Plutons

Characteristics of Host Rocks. The granitic intrusive rocks of the adjacent Toquima and Belmont stocks (Area B, Plate 1) contain environments favorable for authigenic uranium deposits (Class 360; Mathews, 1978). These Cretaceous plutons have yielded nearly contemporaneous radiometric age dates (Toquima, 76.4 m.y.; Belmont, 79.6 m.y.) and may be comagmatic (Ervine, 1973). Both intrusions are predominately quartz monzonite but include rocks from granite to granodiorite, consisting of various amounts of potassium feldspar, sodic plagioclase, quartz, and biotite with traces of muscovite, allanite, apatite, zircon, and monazite (Ervine, 1973; Appendix F). The chief difference between the plutons appears to be the common porphyritic quartz monzonite phase that contains large potassium feldspar phenocrysts in the Belmont stock. Both plutons apparently consist of multiple intrusions, and both are cut by later dikes of granitic aplite and pegmatite, massive quartz, and felsite probably related to volcanism that produced the overlying Tertiary ash-flow tuffs. The Toquima and Belmont stocks intrude Cambrian metasedimentary rock types including crystalline limestone, argillite, quartzite, and schist, which underwent complex folding prior to intrusion. All known uranium occurrences in Area B are present within the plutons themselves, and no uranium concentration appears to have occurred in the county rocks at plutonic margins.

Uranium Occurrences in the Toquima and Belmont Stocks. Eight uranium occurrences are in the plutons of Area B (Plate 2; Appendix C). Seven of these occurrences, the Henebergh Tunnel, Bey, Joker Shaft, Ace Adit, Huebnerite Mill, N and H, and Pine occurrences, are in the Toquima pluton. The largest occurrence, the Hot Claims, is hosted by the Belmont stock. All these occurrences share a number of characteristics. At each occurrence, uranium concentration is limited to fracture fillings and altered granitic rocks immediately adjacent to fractures, and the host rocks have undergone oxidation and argillic and sericitic alteration (Appendix F). These mineralized fractures have a generally north-northeast trend (Gibbs, 1976). Fracture fillings at all occurrences include iron oxide minerals, and kaolinitic clays fill fractures at five prospects (Table 2; Appendix C). The only uranium minerals identified from these occurrences are the uranyl phosphates, autunite and torbernite (Garside, 1973). Uranium is also in accessory allanite, apatite, monazite, and zircon in the host rocks (Gibbs, 1976).

Although all the uranium occurrences of Area B display marked similarities, some characteristics vary between occurrences. At the Henebergh Tunnel, Joker Shaft, and Pine Group prospects, dikes of porphyritic felsite intrude granite or quartz monzonite host rocks along the fracture zones that host uranium (Appendix C). The felsite dikes themselves do not contain appreciable amounts of uranium at any locality and appear unrelated to uranium mineralization. Fluorite and scheelite are present at the N and H prospect and fluorite, scheelite, pyrite, and chalcopyrite at the Ace Adit (Gibbs, 1976), but their relationship to uranium is unclear. Massive vein quartz is also common in several occurrences (Table 2).

Chemically, no consistent correlation between uranium content and the contents of any other element could be discerned from the samples collected during this study (Appendix B-1). However, Gibbs (1976) states that monazite and allanite are present only in zones of anomalous radioactivity and that apatite and zircon are always more abundant in these zones. As mentioned above, copper, fluorine, silicon, and tungsten are locally enriched at some occurrences.

TABLE 2. GAMMA SPECTROSCOPY ANALYSIS OF SELECTED ROCKS FOR FAVORABLE AREA B*

Sample # (MER-)	Uranium Occurrence	Rock Type+	CPS**	Chemical U_3O_8 (ppm)	Calculated cU (ppm)	Equivalent U (ppm)	Equivalent Th (ppm)	eTh/eU	eTh/cU	eU/cU
011	Shale Pit	ft	310	13	11	---	---	---	---	---
012	Shale Pit	fpt	500	184	156	---	---	---	---	---
163	Shale Pit	ft	230	5	---	---	---	---	---	---
013	Red Bird Toquima	hy in fi	400	67	56.8	---	---	---	---	---
014	Bey Group	hy in fi	1100	122	103.5	---	---	---	---	---
015	Ace Adit	hy in fi	1400	77	65	71	11	.16	.17	1.1
016	Ace Adit	hy in fi	2500	273	231.5	127	5	.04	.02	.55
157	Ace Adit	fi	150	1	---	---	---	---	---	---
017	Pine Group	hy in fi	12000	1470	1247	1440	11	.008	.009	1.15
018	Pine Group	hy in fi	5000	234	198	501	5	.01	.025	2.5
019	Green Top	hy in fi	350	49	42	---	---	---	---	---
020	Violet Blue	hy in fi	550	29	25	---	---	---	---	---
021	Huebnerite Mill Prospect	hy in fi	700	226	192	---	---	---	---	---
022	Huebnerite Mill Prospect	hy in fi	1200	5	4.24	---	---	---	---	---
031	Hennebergh Tunnel	fi	220	16	13.6	---	---	---	---	---
032	Hennebergh Tunnel	hy in fi	250	65	55	---	---	---	---	---
033	N and H Group	hy in fi	1500	467	396	---	---	---	---	---
034	N and H Group	hy in fi	1700	93	79	---	---	---	---	---
035	Joker Shaft	hy in fi	3750	653	554	443	16	.04	.029	.80
155	Joker Claims	tss	260	9	7.6	---	---	---	---	---
156	Joker Claims	fi	195	1	.848	---	---	---	---	---
037	Hot Claims	fi	70	3	2.5	5	16	3.2	6.4	2
038	Hot Claims	hy in fi	900	513	435	---	---	---	---	---
039	Hot Claims	hy in fi	2500	747	633	---	---	---	---	---
040	Hot Claims	hy in fi	700	28	24	---	---	---	---	---
042	Hot Claims	hy in fi	2500	1027	871	---	---	---	---	---
043	Hot Claims	hy in fi	600	114	97	---	---	---	---	---
052	Hot Claims	fi	650	194	165	---	---	---	---	---
053	Hot Claims	hy in fi	4000	196	166	---	---	---	---	---
158	Hot Claims	hy in fi	250	4	3.4	---	---	---	---	---
159	Hot Claims	hy in fi	140	3	2.5	---	---	---	---	---
160	Hot Claims	hy in fi	150	7	5.9	---	---	---	---	---
044		fi	100	3	2.5	---	---	---	---	---
049		hy in fi	220	3	2.5	---	---	---	---	---

*Gamma Spectroscopy analysis run by BFEC personnel in Grand Junction, Colorado Office.
+See Appendix B-3. Table of Abbreviations.
**Mt. Sopris Scintillometer SC-132.

Uranium content in the Toquima and Belmont stocks (excluding mineralized zones) averaged 1.9-3.4 ppm (Gibbs, 1976), which is less than the 4.7 ppm average for granitic rocks (Clark, 1966). Thorium content of these rocks averages 9.6-12.2 ppm (Gibbs, 1976), compared to an average thorium value of 320 ppm for granitic rocks (Clark, 1966). Thus these plutons have a range of 2.8 to 6.4 for thorium-to-uranium ratios compared to a 4.3 ratio from granitic rock averages. This indicates that intense leaching of uranium from these plutons has not occurred, except possibly on a very local scale. Thorium-to-uranium ratios are commonly less than unity, as would be expected, in uranium-mineralized areas (Table 2). Maximum uranium content in our samples from the Toquima pluton is 1,470 ppm U_3O_8 in MER-017, a sample of iron oxide-coated granite from the Pine Prospect (Table 2). A U_3O_8 content of 1,027 ppm in a sample of altered quartz monzonite is the maximum uranium assay obtained from the Belmont pluton occurrence.

A number of equivalent U_3O_8-to-chemical U_3O_8 ratios for mineralized samples show disequilibrium in favor of chemical uranium. This could be due to daughter-product leaching but is considered most likely due to recent near-surface enrichment of uranium, as discussed earlier for the Area A occurrences. One sample showed marked disequilibrium in favor of equivalent uranium, suggesting either the leaching of uranium relative to its daughter products or analytical error in this analysis.

As mentioned previously, the uranyl phosphates autunite and torbernite and uranium-bearing allanite, apatite, monazite, and zircon are present at these occurrences. No uranium or uranium-bearing accessory minerals could be identified in some radioactive samples of iron oxide and clay; it appears that the uranium in these samples is adsorbed on the iron oxide and clay minerals.

Both aerial radiometric and hydrogeochemical and stream-sediment reconnaissance studies detected anomalies within Area B. Two small aerially detected radiometric anomalies are in the central part of Area B, near the east margin of the Toquima stock (Plate 3). Several ground-water uranium anomalies are in the Belmont stock drainage area; the anomalies outline a radioactive zone that includes the Hot Claims occurrence (Plate 4).

Summary

The uranium occurrences of Area B are along fracture zones in granitic and quartz monzonitic rocks of the closely related Toquima and Belmont stocks. These rocks are commonly leucocratic and contain high proportions of alkali feldspars and quartz. Fluorite is locally present within hydrothermal veins in these rocks. Texturally, both porphyritic and pegmatitic phases are present within these intrusions, which are postorogenic and which intrude metasediments of greenschist facies. The uranium minerals identified in these occurrences are similar to those listed for authigenic uranium occurrences (Class 360; Mathews, 1978), which these occurrences are considered to be.

The sizes of the various uranium occurrences of Area B appear to be quite variable. Subsurface exploration at the Henebergh Tunnel prospect indicates reserves of less than 25 tons of U_3O_8 at a grade of approximately 250 ppm (Mike Easdon, pers. comm., 1980). Based on comparative sizes of surface exposures, the other Toquima occurrences seem likely to be of a similar or smaller tonnage than the Henebergh deposit. The Hot Claims prospect in the Belmont pluton is considerably larger. It seems almost certain that in excess of 100 tons of U_3O_8 at a grade of more than 100 ppm is within Area B.

Access to the Toquima pluton occurrences is by dirt road from Round Mountain, Nevada, with the exception of the N and H occurrence. The road to the N and H is no longer usable except possibly by motorcycle. Because all the Toquima stock occurrences, except the Bey prospect, are deep within the Toquima Range, they are likely inaccessible in winter. The Hot Claims are accessible by one good dirt road from Belmont, Nevada, and a poorer trail from Manhattan, Nevada. As the Hot Claims lie east of the higher portion of the Toquima Range, they are accessible most of the year.

Speculations on the Origin of the Authigenic Deposits of Area B

Gibbs (1976) concludes that argillic and sericitic alteration and such hydrothermal minerals as pyrite, chalcopyrite, scheelite, quartz, and fluorite (at some occurrences) indicate a low-temperature hydrothermal origin for the Toquima pluton occurrences. The absence of these minerals at most occurrences, and the lack of tetravalent uranium minerals at any locality, does not support a hydrothermal origin, however. In addition, drilling at both the Henebergh and Hot Claims deposits indicate that oxidation and uranium enrichment die out within several hundred feet of the surface. This, coupled with the apparent recent enrichment of chemical uranium in some samples, suggests that these deposits may have formed very recently due to near-surface ground-water migration through prominent fracture zones. More study is needed to accurately determine the mode of origin of these occurrences.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

SUMMARY

In the Tonopah Quadrangle, Paleozoic sediments and metasediments outside unevaluated areas were found to be unfavorable for meeting the base NURE criteria. Tertiary sediments outside favorable Area A are considered unfavorable. Felsic volcanics outside of the unevaluated Northumberland and Mount Jefferson calderas are unfavorable. Plutonic rocks outside of favorable Area B are unfavorable. Mesozoic and Precambrian sediments and metasediments were found to be unfavorable. Intermediate and mafic volcanics and metavolcanics are considered unfavorable. Quaternary sediments also fail to meet the base criteria for uranium favorability.

PLUTONIC ROCKS

Plutonic rocks of Cretaceous to Tertiary age and from gabbro to alaskite granite in composition crop out as numerous small stocks in the western half of the Tonopah Quadrangle. None of these meet the criteria for uranium favorability for plutonic rocks set by Mathews (1978).

Multi-element emission spectroscopy for 18 rock samples (Appendix B-1) taken from various plutons indicates they are not similar in bulk composition to the Toquima and Belmont plutons, both of which are considered favorable. An unexpected result was the difference in bulk chemistry between the Toquima and Belmont plutons and the unnamed pluton immediately south of them at the south end of the Toquima Range (Appendix B-1; Plate 12). This is the largest of the unfavorable plutons and has an area of approximately 40 km^2. No literature on this pluton was found; however, petrologic and chemical studies (Appendix B-1; Appendix F) for eight samples give a range in composition from quartz monzonite to granodiorite; the average uranium content is 1 ppm U_3O_8, and an average eTh/eU ratio is 7, suggesting some uranium depletion. This pluton is probably Cretaceous or Tertiary in age. Eight springs draining this pluton (Plate 4; Plate 6) have anomalous uranium values that average of 72 ppb and have a high of 208 ppb. Two anomalous sediment samples of 22 ppm and 53 ppm U_3O_8 are also associated with this pluton. Thus, uranium is being mobilized and transported from this pluton; however, there is no evidence any significant concentration of uranium has taken place.

The Lone Mountain pluton, 30 km west of the town of Tonopah, is the only other intrusion of interest. It has an areal extent of approximately 32 km^2 and is a multiple intrusion that has phases from gabbro to alaskite granite in composition. The bulk of the composition is considered between quartz monzonite and biotite granite (Bonham and Garside, 1979; Phariss, 1974). Five rock samples taken from the western side of the pluton (Plate 5) have from 1 ppm to 10 ppm U_3O_8 (average 5.4 ppm). KUT values (Table 3) indicate enrichment of uranium in three of the samples. Three springs associated with the margins of the pluton (Plate 4) have anomalous uranium values of 27 ppb, 39 ppb, and 39 ppb. Slight disequilibrium, indicating both enrichment and depletion of uranium, is indicated within the pluton; but no sign of significant uranium concentrations in outcrop was found in the pluton or in the intruded Precambrian sediments.

A small quartz diorite (Silberling, 1959) intrusive body in the Shoshone Range has a spring sample and a stream-sediment sample having 12 ppb and 30 ppm U_3O_8, respectively, associated with it. A small granodiorite plug (Callaghan, 1933) in the Paradise Range has a spring containing 14 ppb U_3O_8 associated with it. Both were field checked and showed no evidence of any significant uranium accumulations.

The aerial radiometric survey revealed an anomaly associated with a small intrusive body between the favorable Area B plutons and the southernmost plutons in the Toquima Range. This is directly over the Barrel Spring "occurrence" where a number of small scattered aplitic dikes intrude quartzite. One of the dikes is uraniferous and has U_3O_8 values between 662 ppm and 13,000 ppm, but the volume of mineralized material at this occurrence is insignificant.

Mineralization at Anaconda's Hall Molybdenum property 48 km north of Tonopah is associated with a small aplitic porphyry. Four samples taken from the presently exposed mineralized portion of the stock have an average U_3O_8 content of <1.5 ppm and an average eTh/eU ratio of 2.8. Uranium is not considered to be associated with this molybendum-enriched pluton.

TABLE 3. GAMMA SPECTROSCOPY ANALYSIS OF SELECTED ROCKS OUTSIDE FAVORABLE AREAS*

Sample # (MER-)	Uranium Occurrence	CPS**	Rock Type+	Chemical U_3O_8 (ppm)	Calculated cU (ppm)	Equivalent U (ppm)	Equivalent Th (ppm)	eTh/eU	eTh/cU	eU/cU
004	---	625	sh	7	59	99	18	.18	3	16.61
005	Barrel Springs	5000	---	662	561	---	---	---	---	---
006	Barrel Springs	10000	---	618	524	---	---	---	---	---
007	Barrel Springs	10000	fi	13000	11024	13300	2860	.22	.26	1.2
008	---	200	sc	79	70	8	21	2.63	.3	.11
009	Lee Hiatt Prospect	425	tb	167	142	---	---	---	---	---
010	Lee Hiatt Prospect	225	ph	11	9.3	---	---	---	---	---
029	---	6000	T	3410	2891	2000	16	.008	.005	.69
036	---	7000	ff, Pzs	4200	3561	2670	1	.0003	.0003	.75
081	---	270	vg	13	11	9	30	3.3	2.7	.82
082	---	270	vg	13	11	9	29	3.2	2.6	.82
083	---	2600	tb of ft	228	193	175	21	.12	.11	.91
084	---	400	tb of ft	50	42	44	25	.57	.60	1.05
085	---	1400	ss	324	275	392	5	.01	.02	1.43
086	---	200	ss	25	21	16	6	.38	.29	.76
087	---	400	hy in fi	31	26	15	10	.67	.38	.58
090	---	180	mv	13	11	8	12	1.5	1.09	.73
092	---	1000	lbs/cs	273	231	245	14	.06	.06	1.06
093	---	85	lbs/cs	2	1.7	2	3	1.5	1.76	1.18
094	---	1790	lbs/cs	553	469	---	---	---	---	---
098	---	120	fi	11	9.3	2	12	6	1.29	.22
099	---	250	fi	7	6	5	13	2.6	2.27	.83
100	---	110	fi	9	7.6	3	11	3.7	1.45	.39
115	---	125	ft	5	4.2	3	11	3.7	2.61	.71
116	---	160	ft	5	4.2	4	14	3.5	3.33	.95
117	---	250	ft	7	6	7	24	3.4	4	1.17
118	---	150	ff	4	3.4	5	12	2.4	3.53	1.47
119	---	95	ii	5	4.2	3	12	4	2.86	.71
120	---	150	ft	5	4.2	3	21	7	5	.71
121	---	280	ft	13	11	16	68	4.25	6.18	1.45
122	---	135	it	4	3.4	3	17	5.67	5	.88
123	---	190	it	6	5.1	4	24	6	4.70	.78
124	---	110	lbs	15	12.7	13	57	4.4	4.49	1.02
125	---	110	ss	9	7.6	6	15	2.5	1.97	.79
126	---	110	fi	6	5.1	4	9	2.3	1.76	.78
128	---	190	fi	10	8.5	5	22	4.4	2.59	.588
129	---	190	ft	6	5.1	2	8	4	1.57	.39
130	---	205	ff	5	4.2	3	14	4.66	3.33	.71
131	---	210	fi	5	4.2	3	22	7.33	5.24	.71
132	---	125	ft	6	5.1	6	12	2	2.35	1.2
133	---	115	fi	1	.848	1	5	5	5.9	.848
134	---	200	ff	11	9.3	5	21	4.2	2.25	.54
135	---	195	it	5	4.24	4	20	5	4.70	.94
136	---	195	iat	3	2.5	6	18	3	7.2	2.4
137	---	110	it	2	1.7	4	14	3.5	8.2	2.4
138	---	225	iat	6	5.1	7	19	2.7	3.72	1.37
139	---	225	ii	7	6	5	15	3	2.5	.83
140	---	150	ff	2	1.7	5	17	3.4	10	2.94
141	---	180	fi	2	1.7	4	14	3.5	8.2	2.35

TABLE 3. GAMMA SPECTROSCOPY ANALYSIS OF SELECTED ROCKS OUTSIDE FAVORABLE AREAS* (Continued)

142	---	120	fi	>1	---	---	---	---	---	---
184	---	435	ss	66	56	54	13	.24	.24	.96
185	---	725	ss	107	91	113	81	71.7	.89	1.24
186	---	360	ss	36	30	44	12	3.67	.40	1.42
187	---	430	ss	29	25	27	11	2.45	.44	2.27
188	---	280	ss	33	28	33	10	3.3	.36	1.18
189	---	470	ss	82	70	68	5	13.6	.07	.97
190	---	450	ch	76	64	70	6	11.67	.09	1.09
191	---	200	ft	8	6.8	7	15	2.14	2.2	1.03
192	---	195	ft	9	7.6	9	35	3.89	4.6	1.18
193	---	195	ft	5	4.2	5	29	5.8	6.9	1.19
194	---	140	ft	5	4.2	2	22	1.1	.52	.48
195	---	140	ft	3	2.5	3	15	5	6	1.2
196	---	180	ft	7	6	5	23	4.6	3.83	.83
197	---	135	ss	3	2.5	4	22	5.5	8.8	1.6
198	---	225	ft	8	6.8	7	29	4.14	4.26	1.03
199	---	110	ii	2	1.7	3	15	3	8.8	1.76
200	---	150	it	2	1.7	3	14	4.7	8.2	1.76
251	---	170	ft	3	2.5	3	17	5.7	6.8	1.2
252	---	350	ls	28	24	22	1	.045	.04	.92
253	---	55	ls	2	1.7	1	1	1	.59	.59
254	---	75	ls	6	5.1	4	2	.5	.39	.78
256	---	100	ch	<1	---	---	---	---	---	---
257	---	425	ch	61	52	51	2	.04	.04	.98
258	---	225	tb/ls	3	2.5	4	24	6	9.6	1.6
259	---	200	it	4	3.4	4	20	5	5.9	1.18
260	---	250	it	5	4.2	4	22	5.5	5.24	.95
261	---	250	vg	6	5.1	5	20	4	3.92	.98
262	---	250	ft	6	5.1	9	45	5	8.82	1.76
263	---	250	lbs	5	4.2	5	23	4.6	5.48	1.19
264	---	225	it	4	3.4	3	22	7.3	6.47	.88
265	---	230	vg	6	5.1	6	24	4	4.70	1.18
266	---	250	it	3	2.5	3	21	7	8.4	1.2
267	---	170	fi	<1	<1	2	13	6.5	<6.4	>2
268	---	170	fi	<1	<1	1	10	10	<10	>1
269	---	170	fi	<1	<1	2	11	5.5	<5.5	>1
270	---	250	ff	5	4.2	5	20	4	4.76	1.19
271	---	200	ff	1	.85	2	10	5	11.76	2.35
272	---	250	ff	5	4.2	6	20	3.33	4.76	1.43
273	---	250	ff	3	2.5	3	22	7.3	8.8	1.2
274	---	225	it	6	5.1	5	15	3	2.94	.98
275	---	180	it	4	3.4	4	22	5.5	6.47	1.18
276	---	140	ft	5	4.2	4	24	6	5.7	.95
277	---	125	ft	1	.85	2	13	6.5	15.3	2.35
278	---	150	ft	4	3.4	4	20	5	5.88	1.29
279	---	175	mv	5	4.2	4	18	4.5	4.30	.95
280	---	65	lbs	<1	---	---	---	---	---	---
281	---	45	ls	1	.85	1	1	1	1.18	1.18
282	---	40	ft	4	3.4	2	1	.50	.29	.59
283	---	283	ft	4	3.4	2	10	5	2.94	.59
284	---	375	ar	9	7.6	98	14	.14	1.84	12.9
285	---	195	vg	9	7.6	8	24	3	3.15	1.05
286	---	180	ii	4	3.4	4	21	5.25	6.17	1.18
287	---	195	ff	4	3.4	4	13	3.25	3.82	1.18
288	---	275	ft	10	8.5	10	23	2.3	2.70	1.18

TABLE 3. GAMMA SPECTROSCOPY ANALYSIS OF SELECTED ROCKS OUTSIDE FAVORABLE AREAS* (Continued)

289	---	120	scs	7	6	7	1	.14	.17	1.17
290	---	140	sts	5	4.2	7	0	0	0	1.67
291	---	1300	sts	45	38	152	43	3.53	1.13	4
292	---	400	cs	12	10	6	19	3.17	1.9	.60
293	---	200	ii	4	3.4	25	83	3.32	24.4	7.36
294	---	140	fi	<1	<1	2	13	6.5	>13	>2
295	---	160	fi	<1	<1	1	11	11	>11	>1
296	---	140	fi	1	.8	2	14	7	17.5	2.5
297	---	140	fi	<1	<1	1	9	9	>9	>1
298	---	140	fi	<1	<1	2	9	4.5	>9	>2
299	---	70	fi	<1	---	0	1	---	---	---
300	---	140	fi	1	.85	3	6	2	7.1	3.5
301	---	1900	s	<1	---	256	0	---	---	---
302	---	110	ls	<1	.85	1	1	1	1.18	1.18
303	---	1300	s	2	1.7	64	3	.05	1.76	37.6
304	---	200	ft	4	3.4	5	21	4.2	6.17	1.47
305	---	215	ft	3	2.6	5	15	3	6	2
306	---	200	fi	3	2.6	4	9	2.3	3.5	1.5
307	---	85	fi	<1	---	1	7	7	>7	>1

*Gamma Spectroscopy analysis run by BFEC Personnel in Grand Junction, Colorado Office.
+See Appendix B-3. Table of abbreviations.
**Mt. Sopris Scintillometer SC-132.

TERTIARY SEDIMENTS OUTSIDE FAVORABLE AREA A

Tertiary sediments consist of conglomerates, sandstone, and siltstones of fluvial origin and lacustrine claystones, shales, diatomites, and limestones. These rocks have localized exposures throughout most of the Tonopah Quadrangle.

Tertiary sediments outside of favorable Area A host two uranium occurrences. At the Can't Miss Group (Class 240 and 530) (Garside, 1973), in the southern portion of Cedar Mountain, concentration occurs along fault contacts between oxidized, silicified vitric-crystal tuff and associated Tertiary tuffaceous sandstone. Petrographic investigation suggests uranium is substituting for calcium in cryptocrystalline apatite to form collophane at this locality (Appendix F). At the Stone Cabin Valley Claims (Class 240), near Five Mile Spring in Stone Cabin Valley, concentration is in intercalated silicified (opalized) lithic sandstones and volcanic conglomerates. Petrologic investigation of Tertiary sediment sample MER-185 indicates uranium is absorbed on clay minerals. Neither the Can't Miss Group nor the Stone Cabin Claims fits the base criteria of 100 tons of U_3O_8 at an average grade of 100 ppm U_3O_8.

The aerial radiometric anomalies investigated in Tertiary sediments were not found to be associated with significant concentrations of uranium in outcrop (Plate 3). No significant stream or sediment anomalies are found associated with these rocks. Tertiary sedimentary rocks within the Tonopah Quadrangle outside favorable Area A are considered unfavorable for 100 tons of U_3O_8 at an average grade of 100 ppm U_3O_8.

PALEOZOIC SEDIMENTS AND METASEDIMENTS OUTSIDE FAVORABLE AND UNEVALUATED AREAS

Paleozoic sediments and metasediments crop out in most of the mountain ranges in the Tonopah Quadrangle. These Paleozoic rocks consist of three assemblages: a miogeosynclinal assemblage of carbonates, a transitional assemblage of shale and limestone in the eastern and central portions of the quadrangle, respectively, and an eugeosynclinal assemblage of siliceous-clastic and volcanic rocks in the extreme western portion of the quadrangle. During Late Devonian to Early Mississippian time, the Roberts Mountain Thrust displaced the eugeosynclinal assemblage eastward over the transitional and carbonate assemblages. Throughout the rest of the Paleozoic, the landscape in the central portion of the quadrangle was dominated by the Antler Highland. Three depositional provinces in the quadrangle are associated with the highland: a conglomerate and carbonate province within the Antler Highland, a carbonate and terrigenous-detrital province to the east of the highland, and a siliceous and volcanic province to the west of the highland (Stewart, 1980; Kay and others, 1964; Kleinhampl and Zoiny, 1967; Langenheim and Larson, 1973; Vitaliano and Callaghan, 1963; Webb, 1958).

Economic deposits of gold, silver, copper, tungsten, and antimony, as well as minor occurrences of uranium, are associated with the contact aureoles where a Mesozoic granitic pluton intruded Paleozic sediments (Dyan, 1916; Ferguson, 1917b, 1921, 1927; Ferguson and Cathcart, 1954; Kral, 1951; Kurfak, 1975; Nolan, 1930, 1935; Silberman and McKee, 1974; Silberman and others, 1978). Two uranium occurrences, the Lee Hiatt Prospect in the southern

Toquima Range and the Titus-Black and Pete Prospect (Garside, 1973) in the central Hot Creek Range (both Class 370), are contact associated. Based on confidential company information, neither of these appear to meet the basic criteria of tonnage and grade for favorability.

Three aerial radiometric anomalies were reported in Paleozoic rocks (Plate 3). One in the northern Toiyabe Range and another in the south-central Hot Creek Range were not found to be associated with significant concentrations of uranium. The third is over the Lee Hiatt and Barrel Springs uranium occurrence. Anomalous uranium, in spring waters of 27 ppb and 21 ppb on the northwestern side of the Paradise Range, was not found to be associated with any concentrations of uranium that could be located on outcrop.

Paleozoic sediments in the Tonopah Quadrangle are considered unfavorable for uranium deposits. Recognition-criteria characteristics for uranium deposits in sedimentary and metamorphic rocks (Mickle and Mathews, 1978) are not present; nor do concentrations of any prospects in these rock types approach minimum-grade and minimum-tonnage requirements. Additionally, no significant HSSR or aerial radiometric anomalies were associated with these rock types.

MESOZOIC SEDIMENTS, METASEDIMENTS, AND VOLCANIC ROCKS

Rocks of Mesozoic age occur in the western third of the study area and comprise four formations of interest. The Triassic Excelsior Formation (Muller and Ferguson, 1936, p. 224), exposed in the Pilot Mountains, is composed of volcanic rocks and sediments with an aggregate thickness exceeding 3000 m.

The Middle Triassic Grantsville Formation has limited exposure in the Shoshone Range but is of interest as a host for the Grantsville mercury mining district. The formation consists of a lower clastic unit, a massive siliceous pebble conglomerate that grades upward into a sandy argillite, and an upper 90-m-thick limestone unit, the host for the mercury ore. The contact ore deposits of silver, lead, zinc, and mercury were formed by the selective mineralization of this limestone by an igneous intrusive rock that is not exposed at the surface (Silberling, 1959). The Grantsville district has produced several thousand flasks of quicksilver. Fluorite is also associated with the Grantsville Limestone Member and the Lunning Formation as replacement deposits in alteration and fault zones (Silberman, 1959; Papke, 1979). No uranium concentration is present in the area.

The Triassic Luning Formation, named by Muller and Ferguson (1936, p. 245), is exposed in the Pilot Mountains, Paradise Range, Shoshone Range, and Cedar Hills. The formation consists predominately of approximately 2400 m of limestone and subordinate shale, argillite, and conglomerate. The only uranium occurrence associated with Mesozoic rocks is in argillite of the Luning Formation in the Paradise Range, at an old mercury mine near Brunton Pass (Appendix C). The Brunton Pass occurrence (Class 370?) was found and drilled by Phillips Uranium Corp. in 1978. The low-grade metasediments are hydrothermally altered. Mineralization has occurred along steeply dipping shear zones. However, concentrations of uranium are below those for the NURE criteria.

The Jurassic Dunlap Formation, named by Muller and Ferguson (1936, p. 250), is in the Cedar Hills, Pilot Mountains, and Shoshone Range. The Dunlap Formation is composed mostly of a clastic sequence of sandstone, conglomerate, and fanglomerate overlain locally by volcanic rocks and limestone. In the Pilot Mountains, over 5,000 flasks of quicksilver were mined, mostly from the limestone and sandstone units of the Dunlap Formation (Foshag, 1928; Phoenix and Cathcart, 1952; Rose, 1961); but no uranium is associated with this mineralization.

Mesozoic rocks in the Tonopah Quadrangle are considered unfavorable for uranium mineralization for these reasons: only one small uranium occurrence is reported; hypogene mineralizing solutions, which accomplished mercury and fluorine mineralization in the area, commonly were not uraniferous; and there are no aerial radiometric or HSSR anomalies within these rocks.

FELSIC VOLCANIC ROCKS OUTSIDE FAVORABLE AND UNEVALUATED AREAS

Felsic volcanic rocks, from rhyolite porphyry to quartz latite in composition, make up the bulk of the rocks exposed in the Tonopah Quadrangle. The majority of these rocks are considered Tertiary in age. They occur as rhyolite plugs, flows, and domes; air- and water-lain tuffs; and thick sequences of ash-flows that grade upward from vitric bases through densely welded to nonwelded tuffs in complete sections.

Laboratory gamma-spectroscopy analyses of 35 felsic volcanic rocks yielded average ratios of eTh/eU = 4.3, eTh/cU = 5.3, and eU/cU = 1.2. These ratios suggest some depletion of chemical uranium in these rocks. Several anomalous stream and water samples from felsic volcanic rocks also indicate release of uranium from these rocks (Plate 4). Several small aerial radiometric anomalies in felsic volcanic rocks (Plate 3), none related to the aforementioned HSSR anomalies, were not found to be associated with anomalous concentrations of uranium in outcrop.

The only uranium occurrence in felsic volcanics is the Can't Miss Group (Class 530, 240) in the southern portion of Cedar Mountain (Garside, 1973). Mineralization occurs along fault contacts between oxidized, silicified vitric-crystal tuff and associated tuffaceous sandstone sediments. Petrographic investigation suggests that uranium is substituting for calcium in cryptocrystalline apatite (collophane). (See discussion on "Speculations of origin of Big Smoky Valley occurrences," this report.) This occurrence does not meet the minimum tonnage and grade requirement for favorability (J. Johnson, pers. comm., 1980).

The felsic volcanic rocks in the Tonopah Quadrangle are considered unfavorable for uranium deposits. Although KUT data (Table 3), the aerial radiometric survey, and HSSR data indicate some uranium mobility, concentrations of uranium within these rocks, such as at the Can't Miss occurrence, appear of small extent and very low grade.

PRECAMBRIAN METASEDIMENTS

Rocks of Precambrian age crop out around the margins of the Lone Mountain pluton approximately 30 km west of Tonopah. Rocks of three formations, from late Proterozoic to Cambrian in age, are represented here: the Wyman Formation, the Reed Dolomite, and the Deep Springs Formation. The Wyman Formation (Maxson, 1934) is composed of marble interbedded with phyllite, quartzite, and calc-silicate hornfels. The Reed Dolomite (Kirk, in Knoph, 1918, p. 27), conformably overlying the Wyman, is a recrystallized dolomite that grades into marble. The Deep Springs Formation (Kirk, in Knoph, 1918, p. 27) conformably(?) overlies the Reed Dolomite and consists of alternating gray thin-bedded marble, mica schist, and lesser amounts of light-gray quartzite. These units have been complexly folded and intruded by mafic dike swarms of unknown age and by the felsic Lone Mountain pluton of Cretaceous age. Albers and Stewart (1972, p. 28) suggest that the Lone Mountain pluton occupies the core of a gently plunging anticline developed in the late Precambrian rocks. The contact between the metasediments and the pluton is described by Bonham and Garside (1979, p. 26) as sharp and discordant in detail. Slight sericitic and chloritic alteration of the exposed pluton was observed in the study area. The Precambrian metasediments seem unlikely for uranium concentrations in the two possible categories considered, the contact-metasomatic class (340) and the allogenic class (370): because of the lack of strong alteration, the apparent poor porosity and permeability of the metasedimentary rocks, and the lack of any observable concentrations of uranium in either the pluton or the Precambrian metasediments.

Surface radiometric readings for the metasediments were from 40 cps to 165 cps, and averaged 83 cps on the Mount Sopris SC-132. No aerial radiometric anomalies were found.

The HSSR study reported three anomalous water values from the Lone Mountain area. A spring north of Lone Mountain, flowing from a rock of granite to quartz monzonite composition, contains 27 ppb uranium. A sample of the granite (MER-127) contained 1 ppm U_3O_8. A well on the east side of the Lone Mountain plutons contains 39 ppb uranium. The well was in quartz monzonite that contains 1 ppm U_3O_8. A spring on the west side of the pluton contains 39 ppb uranium. Three other wells in the area contain between 1.21 ppb and 8 ppb uranium. As mentioned before under the section on felsic and mafic plutons, uranium content of rocks seems to be low, and the somewhat elevated concentrations of uranium in ground water suggest that further studies in the area are needed to determine the true potential of the Lone Mountain pluton as a source of uranium.

QUATERNARY SEDIMENTS

Quaternary sediments found throughout the Tonopah Quadrangle consist of desert wash, colluvium, alluvium, talus, and fan and playa deposits. These sediments are considered unfavorable for uranium deposits. No concentration of uranium was found in these units, although many are downdip from possible source rocks and contain organic material. Carborne radiometric readings were from 40 cps to 150 cps on the Mount Sopris SC-132 scintillometer. These readings are consistent with expected averages for detrital sources; there were no apparently anomalous readings. The aerial radiometric anomalies associated with these sediments were followed up by ground reconnaissance but had no positive results (Plate 3). The HSSR study failed to record any anomalous readings associated with these sediments.

TERTIARY AND QUATERNARY INTERMEDIATE TO MAFIC VOLCANIC ROCKS

Intermediate and mafic volcanic rocks are found throughout the Tonopah Quadrangle. Tertiary intermediate and mafic rocks have their greatest exposure in the Monte Cristo Range, whereas Quaternary basaltic rocks cap large areas of the Pancake and Reveille Ranges and San Antonio Mountains.

Intermediate to mafic volcanic rocks of Tertiary and Quaternary age in the Tonopah Quadrangle are considered unfavorable because of their chemical nature, their stratigraphic position, and lack of evidence indicating uranium enrichment from outside sources.

The chemical composition of such rock types, as pointed out by Pilcher (1978) and others, makes them poor sources of uranium. Coupled with this, the geologic setting, as capping units in most areas, allows these rocks to be mineralized only by ascending uraniferous fluids. Evidence of such mineralization having occurred is completely lacking in surface exposures of the capping intermediate and mafic volcanic rocks examined in this study.

A number of aerial radiometric anomalies were associated with the intermediate and mafic volcanic rocks. Followup surface reconnaissance failed to locate any uranium or anomalous radioactivity in outcrop (Plate 3). One anomalous reading in the northwest corner of the quadrangle near Gabbs is attributed to particulates in the air emanating from the presently operating brucite refinery. Another anomaly over andesites and basalts in the Monte Cristo Range was not checked due to access problems and limited time.

HSSR failed to locate any anomalous water or stream sediments associated with intermediate to mafic volcanic rocks. Uranium values for 20 intermediate volcanic rock samples were from <1 ppm to 7 ppm and had an average of 4.1 ppm. Radiometric readings of intermediate to mafic volcanic rocks were from 65 cps to 225 cps on the Mount Sopris SC-132 scintillometer.

UNEVALUATED ENVIRONMENTS

Environments not evaluated due to lack of time, access, hydrologic data, and access to subsurface data are the Northumberland and Mount Jefferson calderas and the radiometrically important hydrologic system at Warm Springs.

MOUNT JEFFERSON CALDERA

The Oligocene Mount Jefferson caldera, north of Round Mountain, consists of a thick pile of rhyolite ash-flow tuffs that may be a composite sheet. The caldera is within the most rugged and the highest (Mount Jefferson, 3642 m) portion of the Toquima Range. Access to the area is quite limited, and little published geologic information is available. One uranium occurrence, the

Hardscrabble (Class 530), is associated with the northern ring-fracture of the caldera (Meehan and others, 1956). This hydroauthigenic occurrence is in a Tertiary ash-flow tuff that has a background of 6 ppm U_3O_8 and a high of 5,130 ppm U_3O_8. Mineralization appears related to a series of north-northeast-trending faults, but the potential size and grade of this occurrence cannot be determined from surface exposures; and private subsurface data was not available during this study. No water, stream-sediment, or aerial radiometric survey anomalies are associated in or around the Mount Jefferson caldera. Lack of access, subsurface information, and sufficient time for detailed studies prevented in-depth evaluation.

NORTHUMBERLAND CALDERA

The Oligocene Northumberland caldera lies within the Toquima Range just north of the Mount Jefferson caldera. Good exposure of the east half of the 20-mi-wide caldera can be seen in the Northumberland Canyon; here a sequence of ash flows, lava flows, intercaldera landslide blocks of Paleozoic sedimentary rocks, and postcaldera sedimentary fill are visible. Particularly well exposed are the thick, composite quartz latite Northumberland Tuff, the eruption of which is believed to have caused the creation of the caldera, and the postcollapse rhyolite tuff of Hoodoo Canyon (McKee, 1974a, 1974b; Bonham and Garside, 1974a, 1974b).

There are two uranium occurrences we believe to be associated with the ring fracture system, the Rainbow Claims (Garside, 1973; Meeham and others, 1956) and the Jane Prospect. Both occurrences are of the hydroallogenic class (540) and are in altered and brecciated Paleozoic sediments of the Vinini Formation. Petrology for these two occurrences includes the uranium mineral carnotite and uranium possibly adsorbed onto carbonaceous matter at the Rainbow Claims. Neither appears likely to contain 100 tons of U_3O_8 at an average grade of 100 ppm U_3O_8.

Within this unevaluated area are 11 water anomalies, which have uranium values from 9 ppb to 31 ppb (average 15 ppb), and 2 stream-sediment anomalies have 17 ppm U_3O_8 and 22 ppm U_3O_8. No anomaly was found to be associated with uranium concentration in outcrop. No aerial radiometric anomalies are associated with the Northumberland caldera.

Two private companies presently have claims staked over most of the caldera and surrounding areas and are still in the process of evaluating their properties. Lack of access to this information has made it impossible to ascertain favorability of the Northumberland caldera and associated areas.

HYDROLOGICAL SYSTEM AT WARM (NANNY GOAT) SPRINGS

Three springs in the extreme south of the Hot Creek Range near Warm Springs, Nevada, are considered to be of possible importance. A cold spring, found a mile northwest of Warm Springs, contains 18 ppb uranium and drains a white felsic crystal tuff (MER-279) that contains 5 ppm U_3O_8. The tuff is presently considered to be at radiometric equilibrium (Table 3). Two hot springs (60°C) rise from a brecciated fault zone in Paleozoic limestone at Warm Springs Station (Garside and Schilling, 1974). The one to the west drains into a fish pond, and the one to the east runs down a trench into the local swimming pool; MER-311 and MER-313 have readings (Mt. Sopris SC-132) of 200 cps and 1,900 cps and chemical uranium values of <1 ppb and 5 ppb, respectively. Samples MER-301, 302, and 303 of sinter and tuff around the hot springs have uranium values of <1 ppm, <1 ppm, and 2 ppm, respectively. Time to study these springs and the surrounding rocks was not available. Therefore this area of hot- and cold-water springs was left essentially unevaluated.

RECOMMENDATIONS TO IMPROVE EVALUATION

The most important areas on which to improve evaluation are the Northumberland and Mount Jefferson calderas. The cheapest method would be to obtain drilling information from the companies presently drilling in the area. Due to access problems into the Mount Jefferson caldera, helicopter support could be of great assistance; the same applies for access problems in the Toiyabe, Monitor, and Hot Creek Ranges for rock and water sampling. Followup studies of the Lone Mountain pluton, as a possible source rock, as well as the southern pluton in the Toquima Range, to establish age and chemical relation to the favorable Belmont pluton to the north are warranted. Most costly, but of great importance, would be subsurface and hydrologic studies of the major basins in the area.

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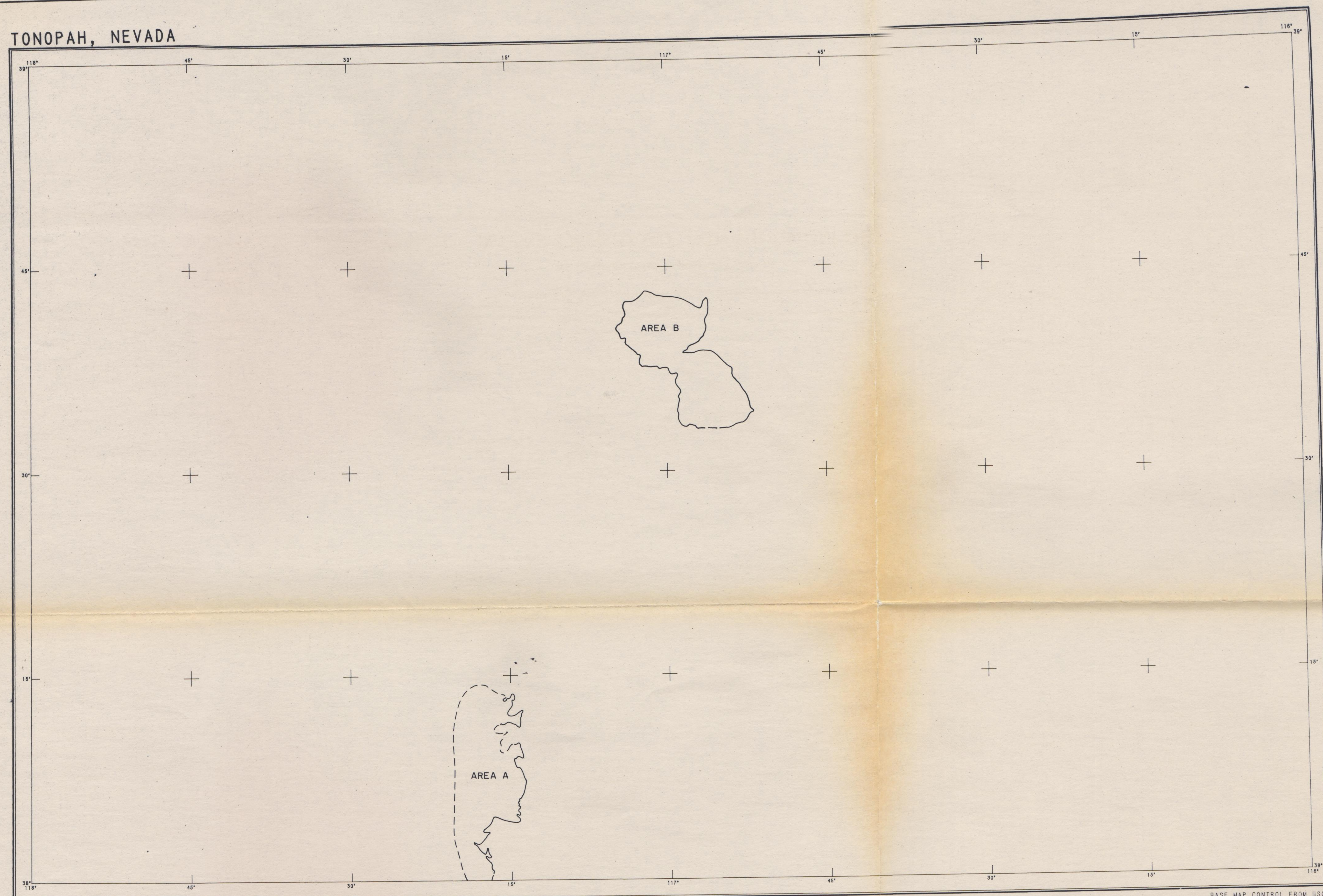
TONOPAH, NEVADA



EXPLA ANATION

AREA A — Easte ern Big Smoky Valley

AREA B — Southe thern Toquima Range

– – – – – – Loss of contact under alluvium

———— Outcr crop

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

5 0 5 10 15 20 25 MILES

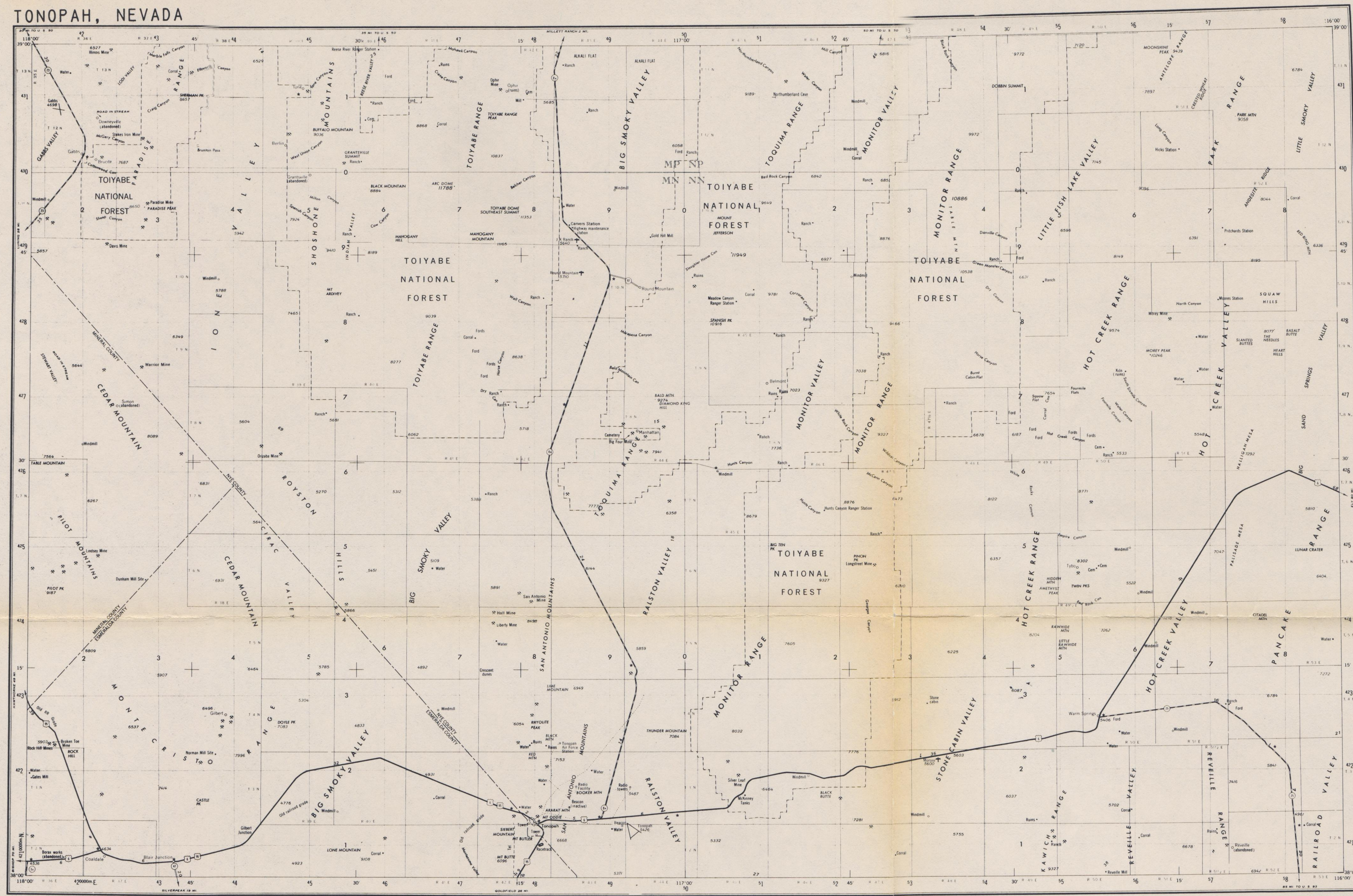
5 0 5 10 15 20 25 KILOMETERS

BASE MAP CONTROL FROM USGS

Plate 1. AREAS FAVORABLE FOR URANIUM DEPOSITS

April, 1981
Plate 1.

TONOPAH, NEVADA



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENER

BASE MAP CONTROL FROM USGS

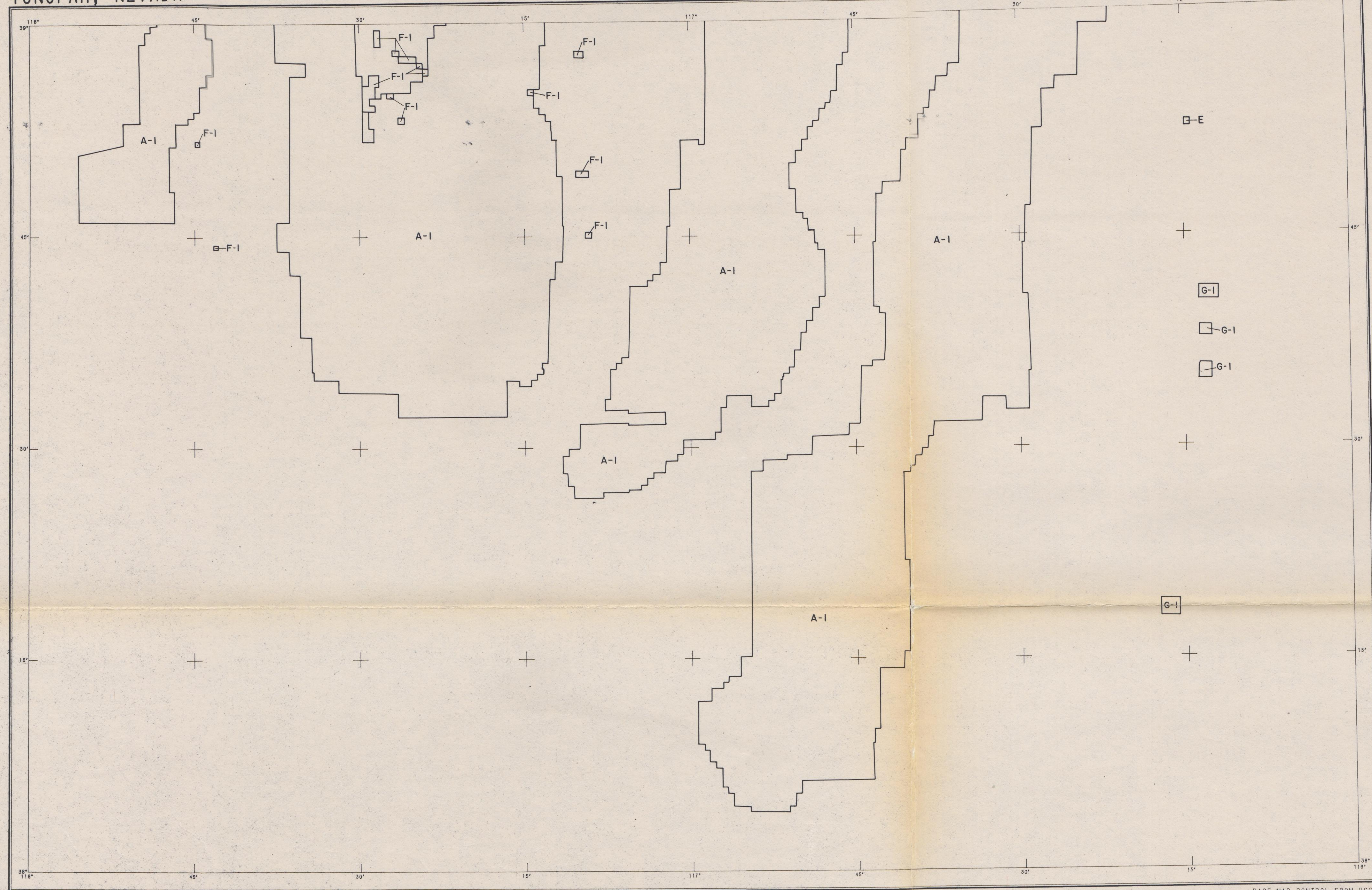
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 15. CULTURE

April, 1981
Plate 15.

TONOPAH, NEVADA



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E. Bureau of Reclam... ...mation Withdrawn Lands

F. Indian Lands
F-1 Yomba India... ...ian Reservation

G. Government Insta... ...tallation
G-1 Department of Energy Nevada Test Site

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 14. GENERALIZED LAND STATUS

April, 1981
Plate 14.

TONOPAH, NEVADA

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April, 1981
Plate 13.

TONOPAH, NEVADA

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS
COMPILED BY GEODATA INTERNATIONAL, INC., 1979

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 12. GENERALIZED GEOLOGIC MAP OF THE TONOPAH QUADRANGLE

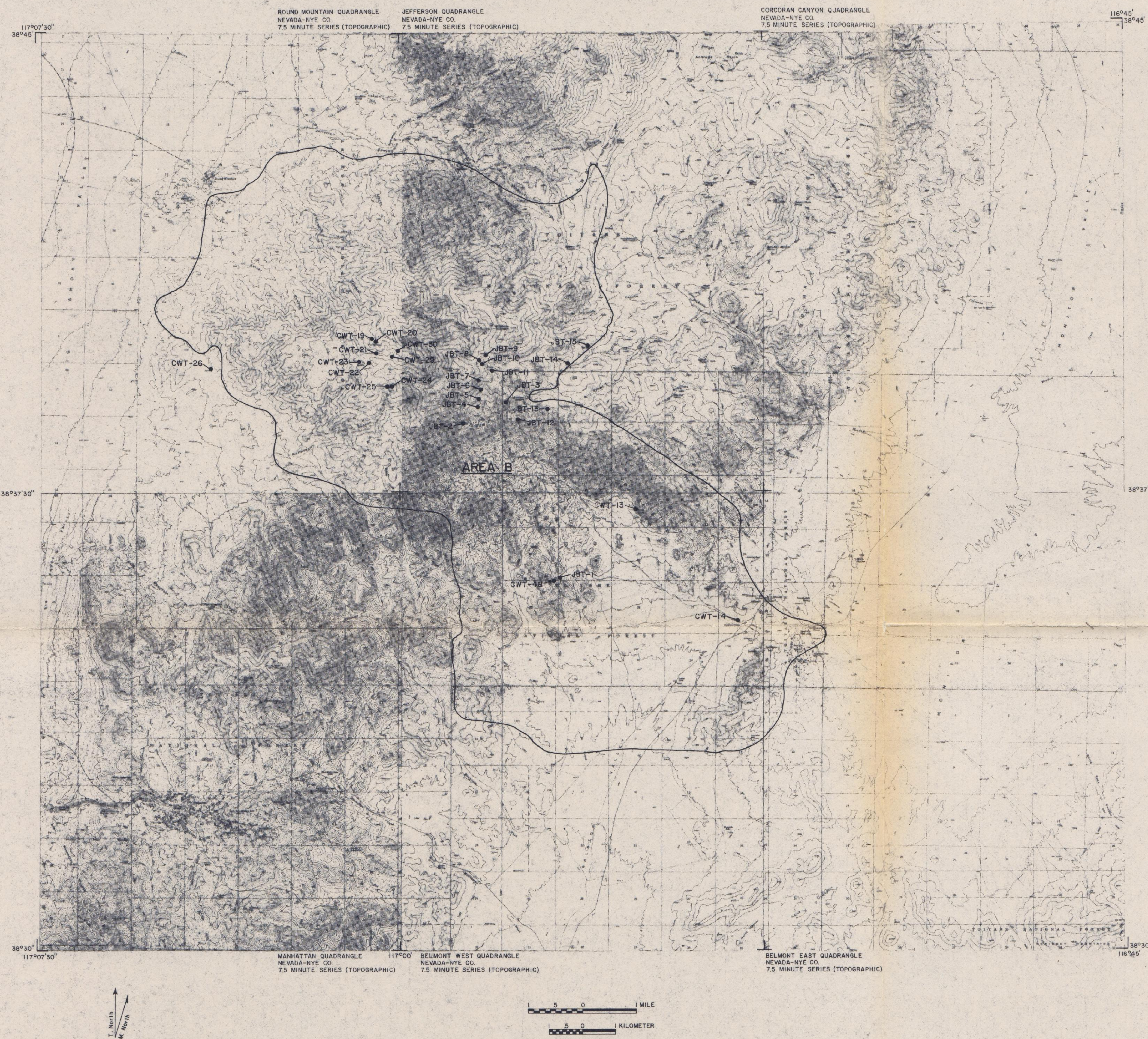
EXPLANATION

DESCRIPTION OF MAP UNITS

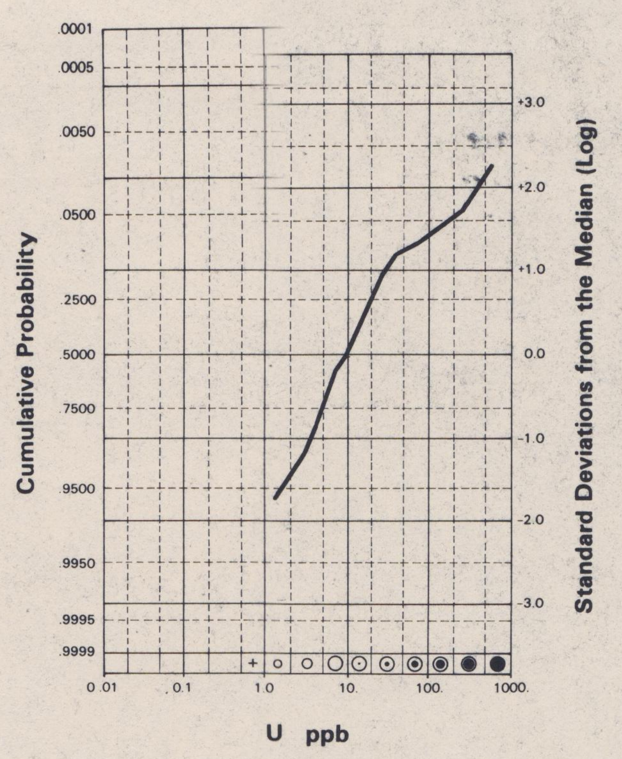
QUATERNARY	Qs	Sediments
	Qb	Basaltic Rocks
TERTIARY	Ts	Tertiary Sedimentary Rocks
	Timv	Tertiary Intermediate and Mafic Volcanics
	Tfv	Tertiary Felsic Volcanics
MESOZOIC	Mfp	Mesozoic Felsic Plutons
	Mmp	Mesozoic Mafic (+ Intermediate) Plutons
	Msv	Mesozoic Sedimentary (+ Volcanic) Rocks
PALEOZOIC	Ps	Paleozoic Sedimentary Rocks
PRECAMBRIAN	PCs	Pre-Cambrian Metasedimentary Rocks

April, 1981
Plate 12.

TONOPAH, NEVADA



SAMPLE NUMBER	GEOCHEMICAL CONCENTRATION	U
CWT-13	⊙	21
CWT-14	⊙	38
CWT-19	○	3
CWT-20	○	2
CWT-21	⊙	20
CWT-22	⊙	19
CWT-23	⊙	18
CWT-24	●	575
CWT-25	⊙	14
CWT-26	⊙	23
CWT-29	⊙	14
CWT-30	○	4
JBT-1	◉	460
JBT-2	◉	80
JBT-3	⊙	22
JBT-4	○	4
JBT-5	○	6
JBT-6	⊙	11
JBT-7	○	3
JBT-8	○	4
JBT-9	○	2
JBT-10	○	3
JBT-11	○	4
JBT-12	⊙	20
JBT-13	○	4
JBT-14	○	4
JBT-15	○	3
CWT-48	○	5



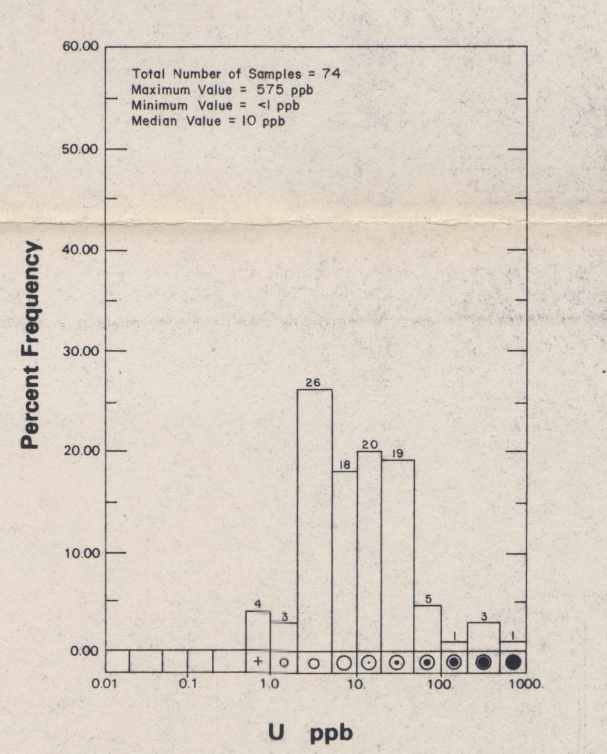
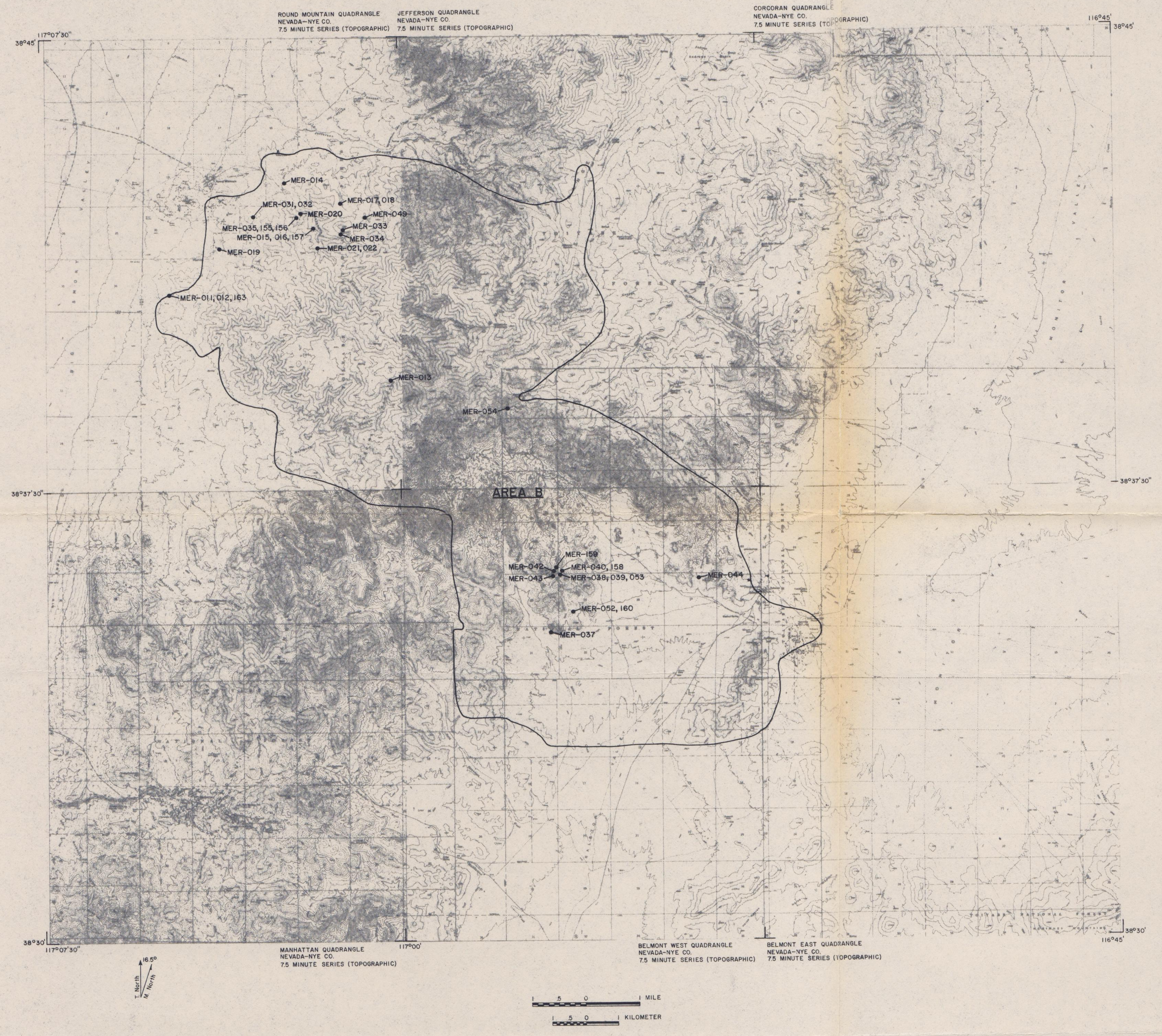


Plate 11. DETAIL OF FAVORABLE AREA B: WATER SAMPLES–URANIUM VALUES

April, 1981
Plate 11.

TONOPAH, NEVADA

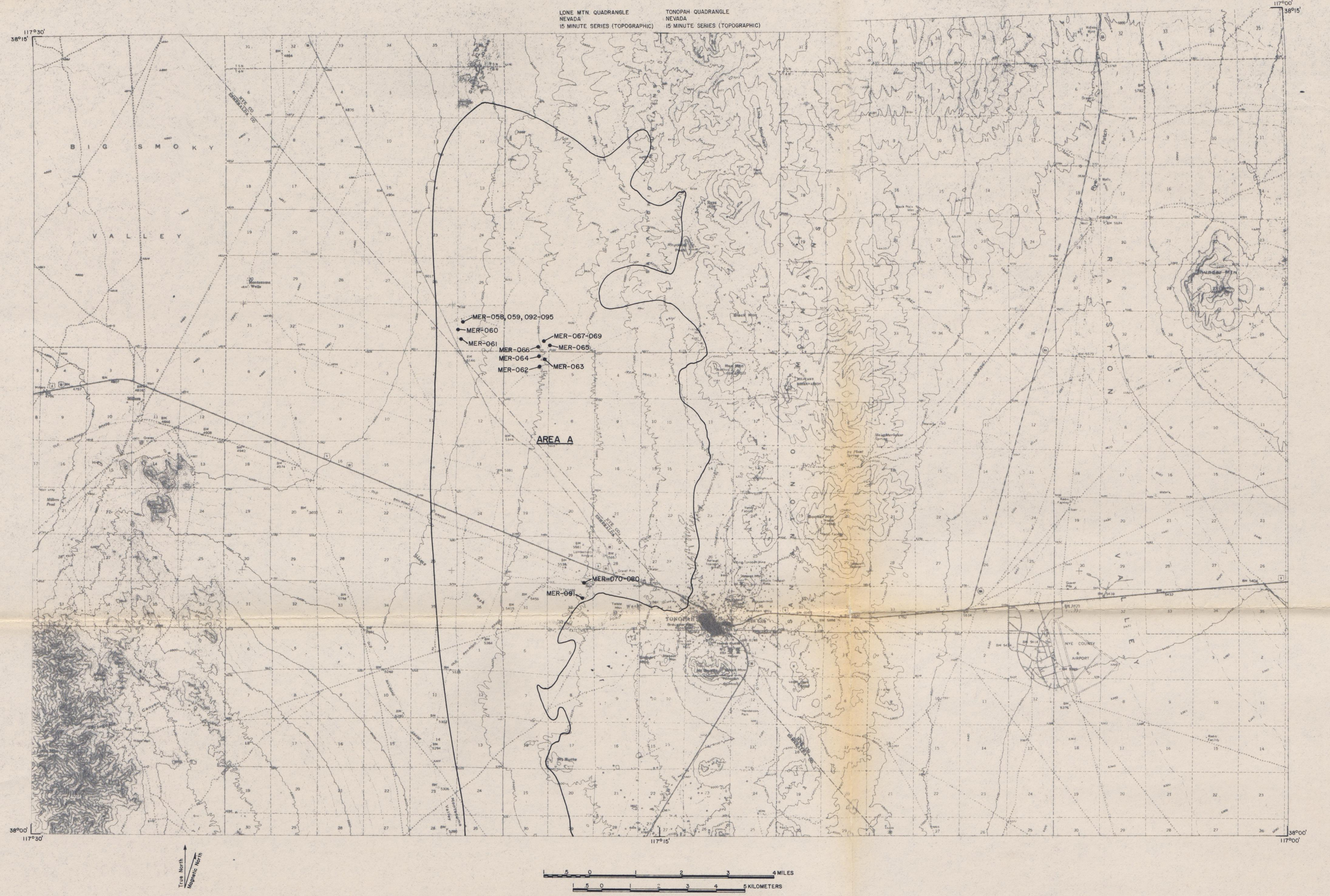


SAMPLE NUMBER	ROCK TYPE	U_3O_8 (ppm)
MER-011	FT	13
MER-012	FPT	184
MER-013	HY in FI	67
MER-014	HY in FI	122
MER-015	HY in FI	77
MER-016	HY in FI	237
MER-017	HY in FI	1,470
MER-018	HY in FI	234
MER-019	HY in FI	49
MER-020	HY in FI	29
MER-021	HY in FI	226
MER-022	HY in FI	5
MER-031	FI	16
MER-032	HY in FI	65
MER-033	HY in FI	467
MER-034	HY in FI	93
MER-035	HY in FI	653
MER-037	FI	3
MER-038	HY in FI	513
MER-039	HY in FI	747
MER-040	HY in FI	28
MER-042	HY in FI	1,027
MER-043	HY in FI	114
MER-044	FI	3
MER-049	HY in FI	3
MER-052	FI	194
MER-053	HY in FI	196
MER-054	P_3S	22
MER-155	FI	9
MER-156	FI	1
MER-157	FI	1
MER-158	HY in FI	4
MER-159	HY in FI	3
MER-160	HY in FI	7
MER-163	FT	5

Plate 10. DETAIL OF FAVORABLE AREA B: ROCK SAMPLES-URANIUM VALUES

April, 1981
Plate 10.

TONOPAH, NEVADA



SAMPLE NUMBER	ROCK TYPE	U_3O_8 (ppm)	P (ppm)	Ca (ppm)
MER-058				
MER-059	CS	◉ 560	–	42,300
MER-060	SS	⊙ 243	–	42,400
MER-061	SH	○ 3	–	37,800
MER-062	SH	● 1,820	–	42,400
MER-063	SH	◉ 560	–	42,400
	CS	◉ 560	–	42,400
MER-064	SS	⊙ 103	–	25,900
MER-065	SS	◉ 289	–	29,400
MER-066	SS	⊙ 184	–	42,400
MER-067	CS	● 1,307	–	42,400
MER-068	STS/SS	◉ 467	–	42,300
MER-069	STS	◉ 401	–	42,300
MER-070	LBS/OP	◉ 415	–	42,300
MER-071	LBS	◉ 499	11,200	18,500
MER-072	LBS	● 1,160	67,700	80,600
MER-073	LBS	● 940	52,700	>100,000
MER-074	LBS	○ 15	880	>100,000
MER-075	LBS	● 500	22,500	67,500
MER-076	LBS	○ 7	1,460	1,360
MER-077	LBS/OP	⊙ 20	<100	300
MER-078	LBS	◉ 283	19,400	29,700
MER-079	LBS/OP	◉ 133	783	300
MER-080	LBS/OP	○ 10	489	300
MER-091	LBS/OP	⊙ 60	10,100	12,700
MER-092	LBS/CS	◉ 273	17,300	52,400
MER-093	LBS/CS	∘ 2	707	16,100
MER-094	LBS/CS	◉ 553	58,900	70,200
MER-095	LBS/CS	⊙ 72	28,600	27,500

Plate 9. DETAIL OF FAVORABLE AREA A: ROCK SAMPLES-URANIUM AND PHOSPHORUS VALUES

April, 1981
Plate 9.

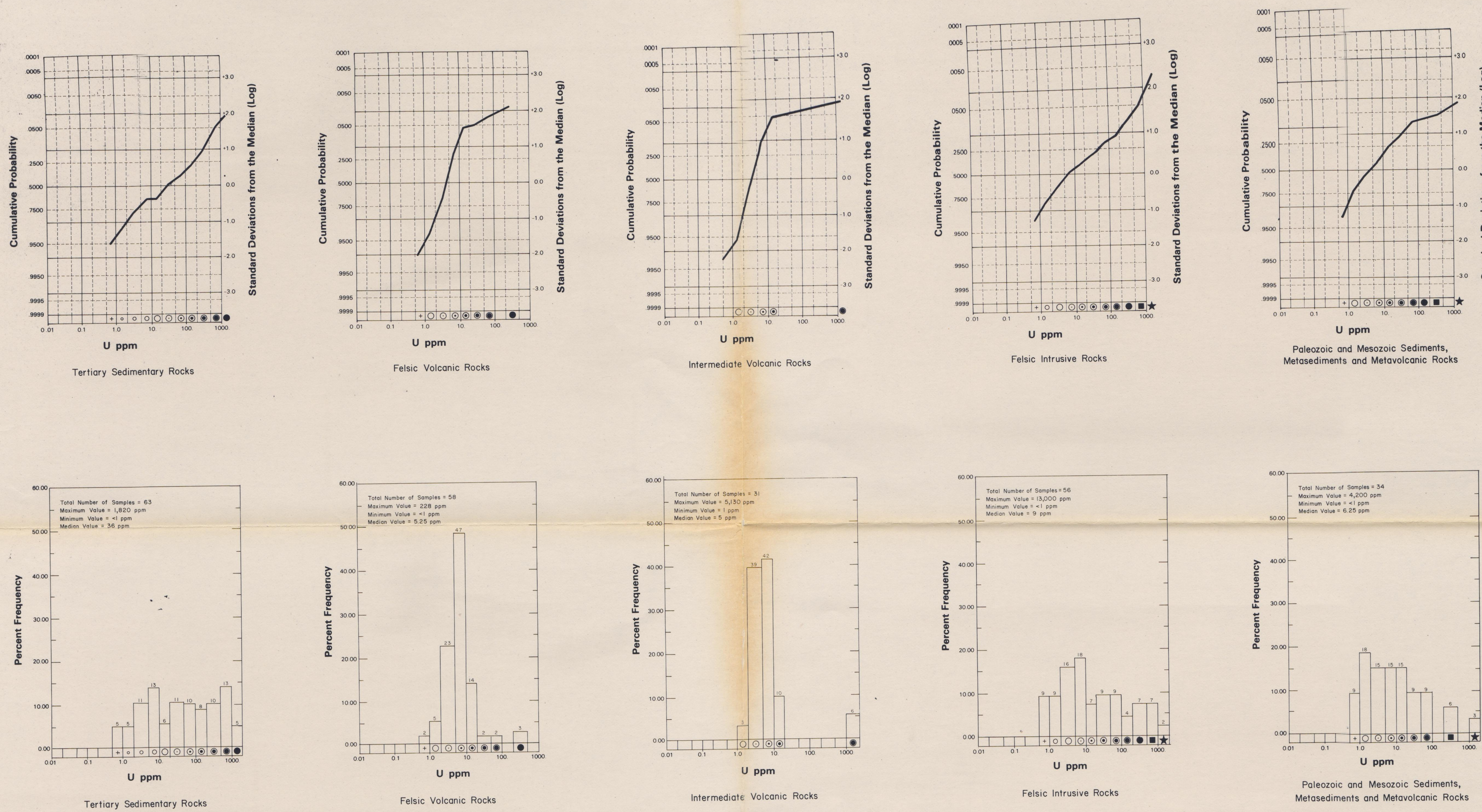
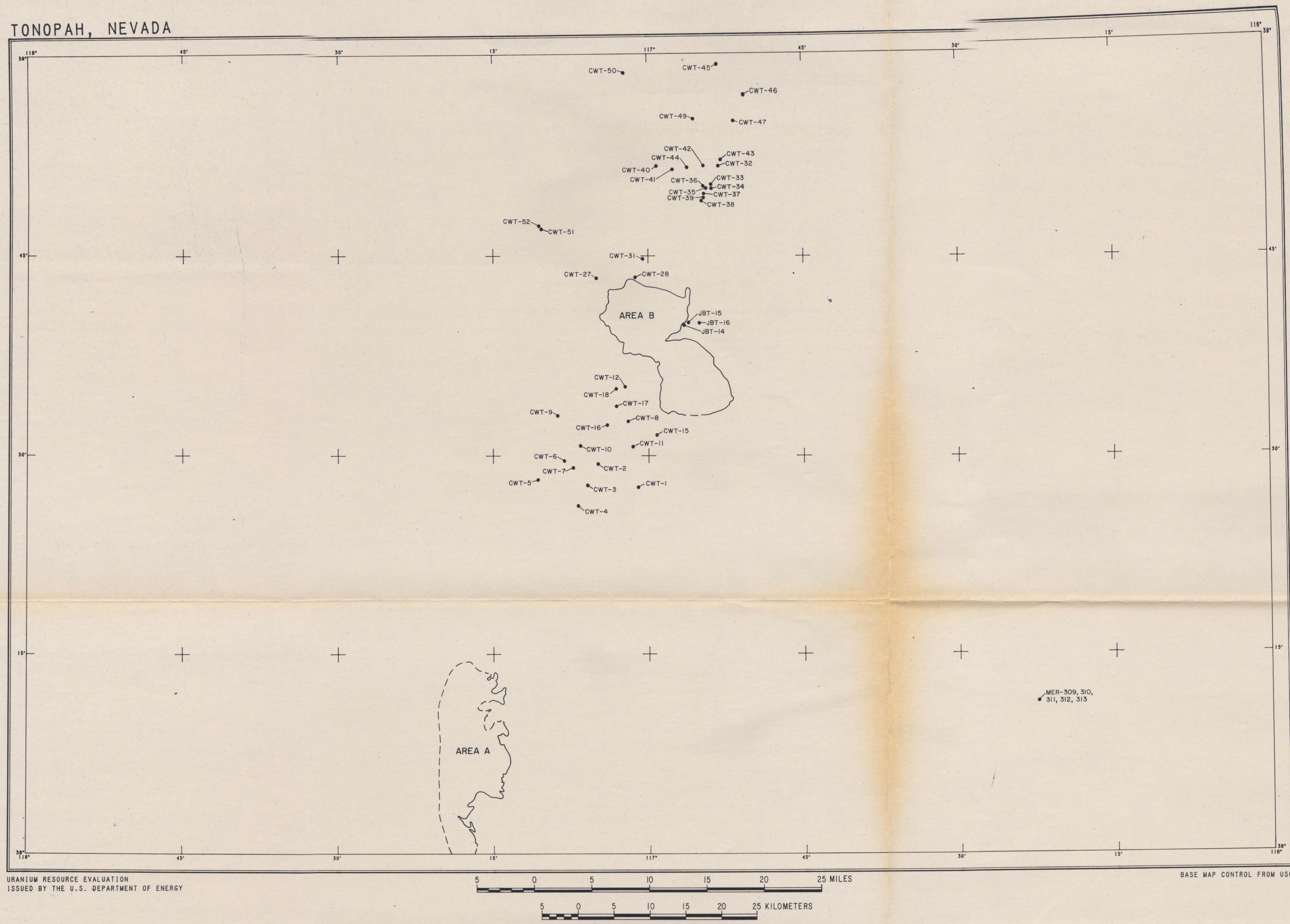


Plate 8. CUMULATIVE PROBABILITY AND PERCENT FREQUENCY FOR SELECTED ROCK TYPES

April, 1981
Plate 8.



EXPLANATION

CWT, JBT, MER collected by Bendix Field Engineering Corporation for Tonopah Quadrangle

Plate 7. LOCATION MAP OF GEOCHEMICAL SAMPLES - WATER

April, 1981
Plate 7.

TONOPAH, NEVADA

URANIUM RESOURCE EVALUATION.
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

Plate 6. DRAINAGE

April, 1981
Plate 6.

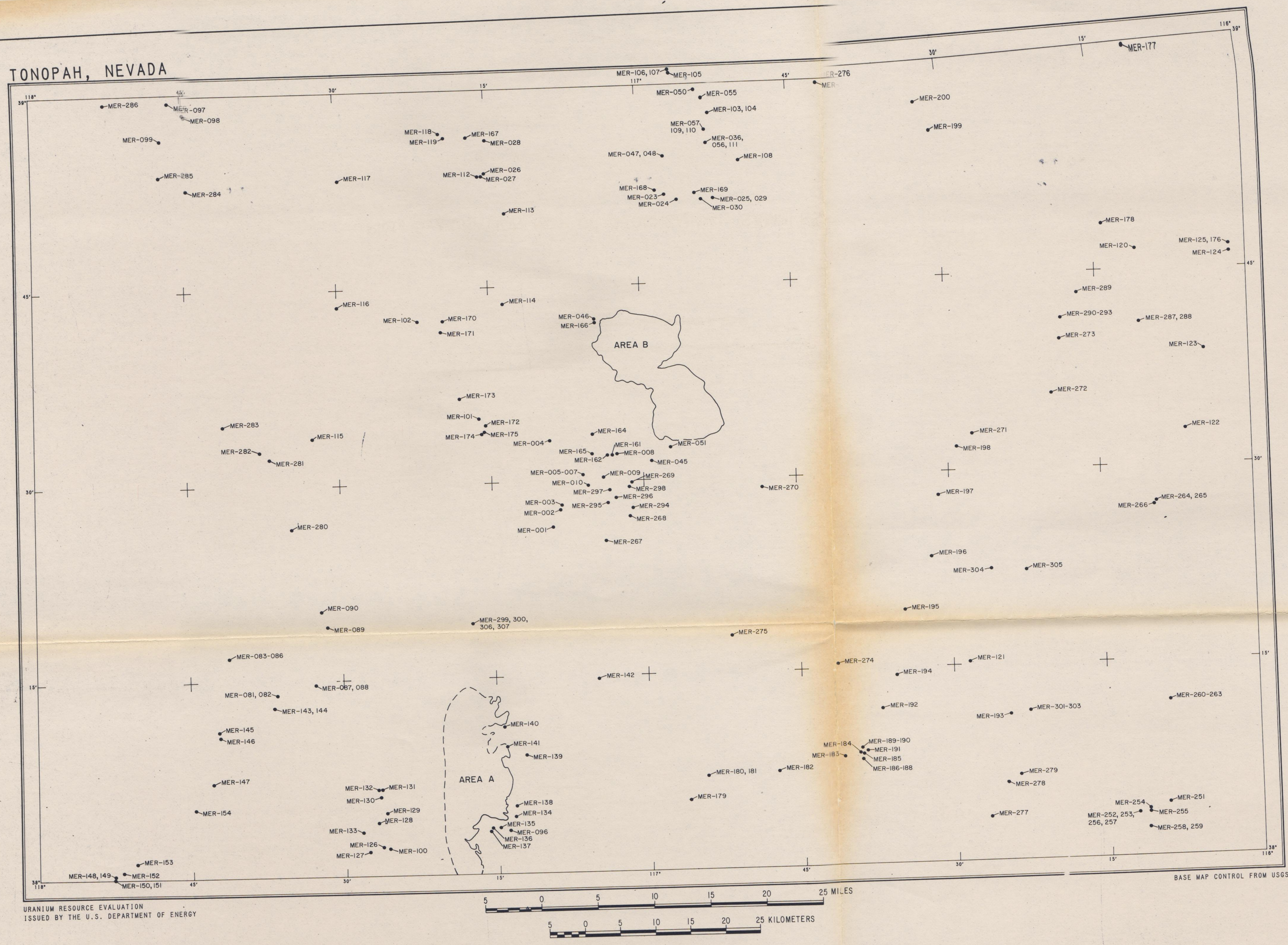


Plate 5. LOCATION MAP OF GEOCHEMICAL SAMPLES-ROCK

April, 1981
Plate 5.

EXPLANATION

HSSR POINT ANOMALIES

○ = Uranium in sediments (ppm)

◇ = Uranium in ground water (ppb)

Plate 4. INTERPRETATION OF DATA FROM HYDROGEOCHEMICAL AND STREAM-SEDIMENT RECONNAISSANCE

April, 1981
Plate 4.

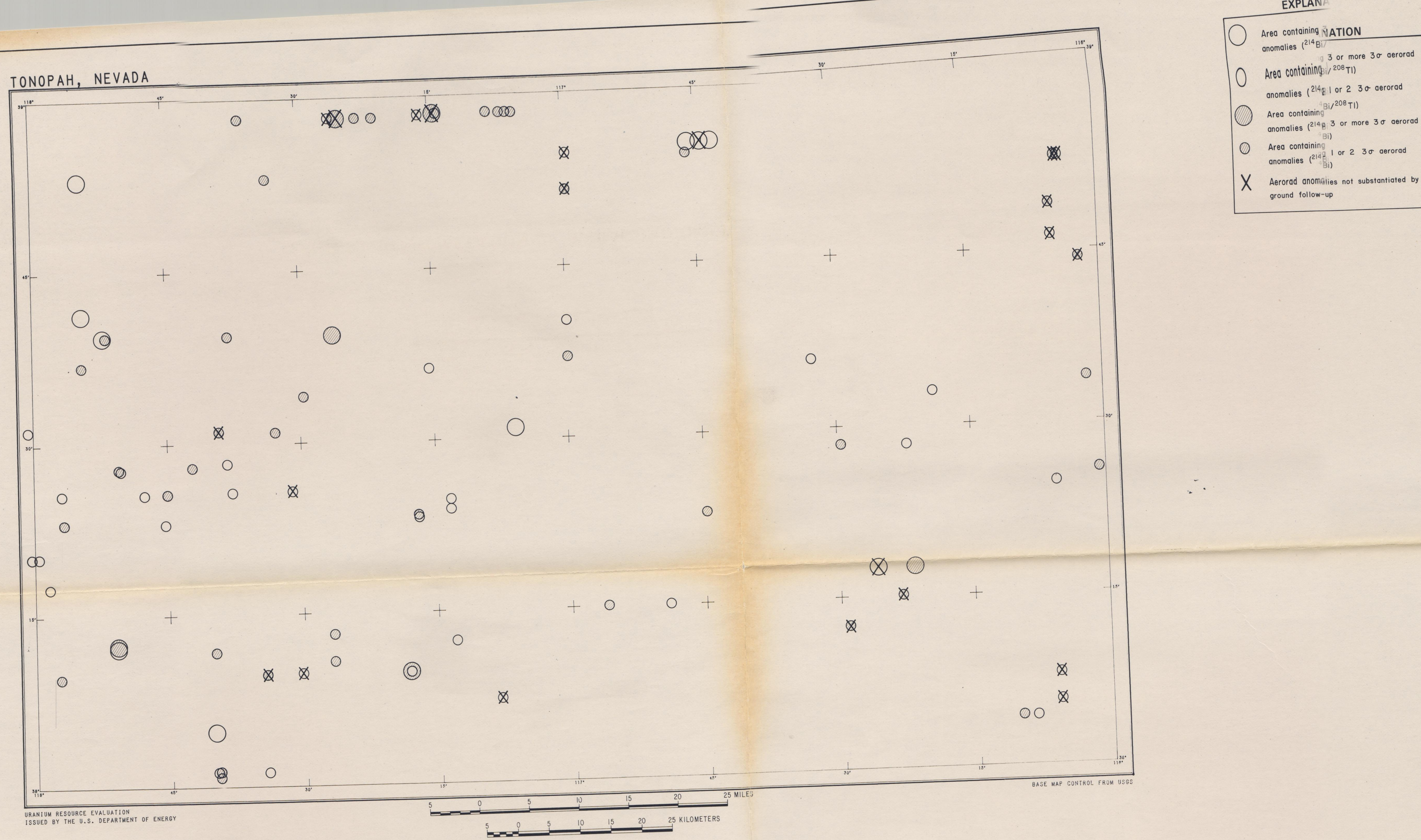
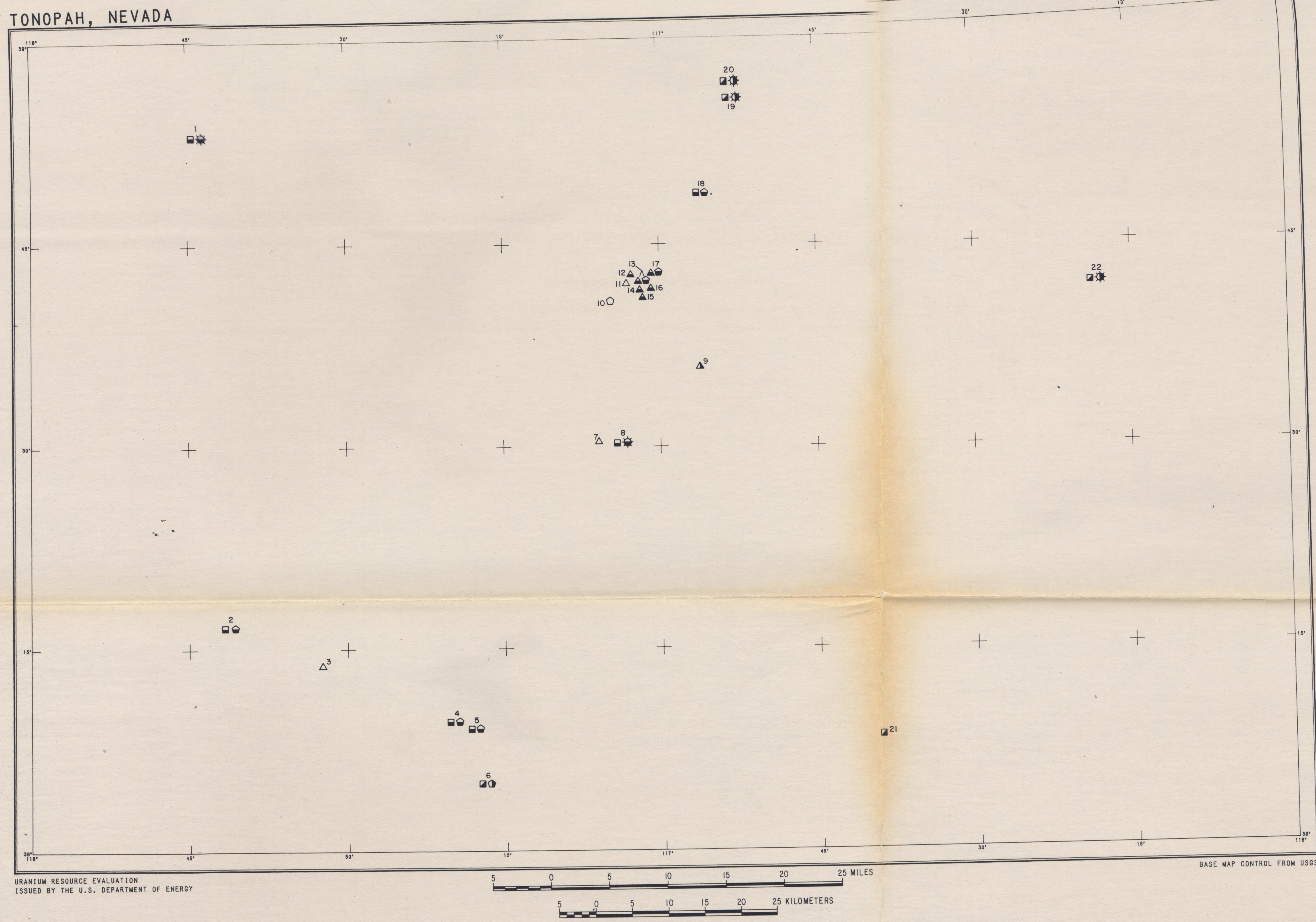


Plate 3. INTERPRETATION OF AERIAL RADIOMETRIC DATA

April, 1981
Plate 3.



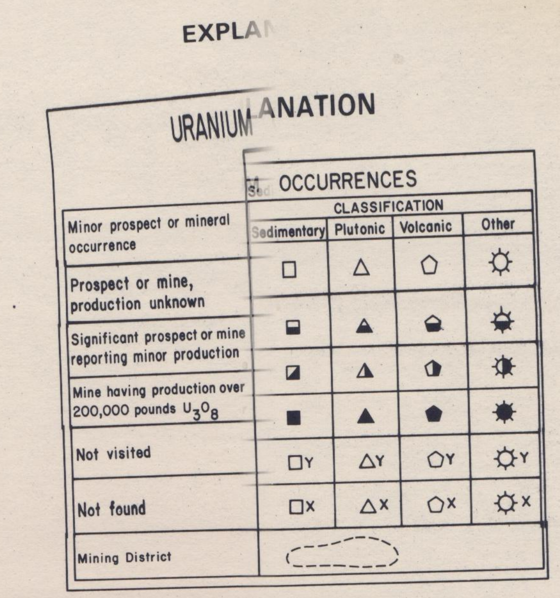


Plate 2. URANIUM OCCURRENCES

April, 1981

Plate 2.