UNITED STATES DEPARTMENT OF THE INTERIOR

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Uranium Potential of the Big John Caldera,
Beaver County, Utah

By

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URANIUM POTENTIAL OF THE BIG JOHN CALDERA,
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T. A. Steven, C. G. Cunningham, and J. J. Anderson

The Big John caldera is a small subsidence structure in the Marysvale volcanic field, high along the western flank of the Tushar Mountains in west-central Utah (fig. 1). This caldera formed 22 m.y. ago in response to ash-flow eruptions of the Delano Peak Tuff Member of the Bullion Canyon Volcanics. Little, if any, mineralization took place during or shortly after caldera subsidence, but subsequent geologic events produced several environments that seem favorable for the occurrence of uranium deposits. This brief report outlines the geologic framework of these environments and is intended to serve as a guide for more detailed investigations and possible exploration of the more favorable areas.

Precaldera geology

The geologic history of the Marysvale volcanic field (Steven and others, 1978; Rowley and others, 1979) chronicles the development of many local volcanoes the periods of activity of which ranged from sequential to partially overlapping and concurrent. The products from the many local centers coalesced into a broad volcanic plateau surmounted by the crests of the larger volcanoes. Initial activity built a large composite volcano of typically porphyritic intermediate-composition lavas and breccias in the northern Tushar Mountains sometime before 30 m.y. ago. Subsequently, flank eruptions formed local volcanoes around the margins of the composite volcano, and ash-flow tuff sheets from local and distant sources lapped onto the flanks of the older volcano and intertongued marginally with it. Most of the locally derived rocks are included in the Bullion Canyon Volcanics, a major volcanic unit in the northern part of the Marysvale volcanic field. Only a small segment of the southern flank of the Bullion Canyon volcanoes is shown on figure 1. The 30-29 m.y. old (Fleck and others, 1975) Wah Wah Springs Tuff Member of the Needles Range Formation, erupted from a source in the Great Basin area many kilometers to the west, is a key stratigraphic marker unit in this assemblage. It rests directly on prevolcanic sedimentary rocks over wide areas of western Utah, but overlaps and wedges out against the flanks of the older volcano in the northern Tushar Mountains (Steven and Cunningham, 1979a).

After the Wah Wah Springs Tuff Member was emplaced, a series of volcanoes began to form in the southern part of the Marysvale volcanic field. These volcanoes consist largely of mafic intermediate-composition lava flows and volcanic breccias that have been called the Mount Dutton Formation (Anderson and Rowley, 1975, p. 24). Mount Dutton volcanoes are scattered across a wide area, from the Sevier Plateau on the east, across the northern Markagunt Plateau and southern Tushar Mountains, to the Black Mountains on the west. Products from these volcanoes overlap northward and in part intertongue with concurrently erupted rocks from the Bullion Canyon volcanoes in the northern Tushar Mountains. Local ash-flow tuff units are interlayered with both the Bullion Canyon and Mount Dutton assemblages.

At the time the Big John caldera formed, about 22 m.y. ago, this part of the Marysvale volcanic field was extremely active; some of the Bullion Canyon volcanoes were still erupting but in diminished volumes, and many of the Mount Dutton volcanoes to the south were still vigorously active. A major regional ash-flow tuff sheet, the Osiris Tuff, was erupted from a caldera source to the northeast and covered the lower flanks of all the older volcanoes. This period of intense activity continued through the development of the Big John caldera described next.

Big John caldera

Shortly after the Osiris Tuff was emplaced but still within analytical uncertainty of a K-Ar age of 22 m.y. (Steven and others, 1979, p. 21), the lower ground on the volcanic plateau between the major Bullion Canyon and Mount Dutton volcanoes was the site of violent ash-flow eruptions that emplaced the crystal-rich quartz latitic Delano Peak Tuff Member of the Bullion Canyon Volcanics. This unit largely filled the low areas between older volcanoes and puddled to thicknesses of 300 m in some of the valleys there (fig. 1). It lapped out marginally against older volcanoes to the north, east, and south. Its western extent is not known, however, and it could have spread many kilometers in this direction. The sheet appears to have had a moderate volume measured in terms of tens of cubic kilometers; it definitely was not a major regional sheet with a volume of hundreds of cubic kilometers.

The Delano Peak ash-flow eruption led to collapse of the source area to form the Big John caldera. The subsided area measures about 10 km across N-S and 6 km across E-W; the amount of subsidence along its clearly defined eastern margin is in excess of 300 m. Big John Flat near the center of the subsided area (fig. 1) is the geographic feature for which the caldera is named. The western margin of the subsided block is poorly exposed and its character is difficult to ascertain. No sharp structural boundary has been found, and a distinct possibility exists that on this side, the subsided rocks merely bent down across a hinge zone to form a trapdoor; and was block faulted only along the east and southeast.

At the surface the eastern margin of the Big John caldera is everywhere marked by a topographic wall along which postsubsidence lava flows and welded tuffs are plastered against a steep slope cut across presubsidence rocks (fig. 1). The northern part of this perimeter is especially important, for here it can be shown that subsidence followed immediately after eruption of the Delano Peak Tuff Member and preceded deposition of the next younger volcanic units in the same area. From the abrupt truncation of the Big John caldera by the younger Mount Belknap caldera near Bullion Pasture (fig. 1), southeastward for 6 km through Delano Peak to the vicinity of Mount Holly, the high divide marking the crest of the Tushar Mountains consists largely of densely welded, flat-lying Delano Peak Tuff Member (fig. 1, unit Tbd) as much as 220 m thick. West of the divide, these flat-lying rocks are cut off abruptly by an irregularly eroded, westward-sloping wall that was covered by lava flows and local welded tuffs of the upper Bullion Canyon Volcanics (fig. 1, unit Tbu) which flowed down the wall and accumulated against it. The oldest of these upper units was a local thin rhyolitic welded ash-flow tuff that was deposited here and there on the wall northwest of Delano Peak and became strongly lineate by secondary flow down the wall while it was welding. This unit is overlain by dark, poorly porphyritic, mafic intermediate-composition lava flows that were erupted from sources to the east and flowed westward across the scarp to form a thick sequence of steeply dipping flows that filled the eastern part of the subsided block. Several erosional windows cut through the younger caldera fill, east and south of Big John Flat, expose these same postcaldera flows, indicating that the floor of the caldera also was widely covered during the same period of eruption.

The south wall of the caldera consists of a mixed assemblage of Bullion Canyon Volcanics and Mount Dutton Formation, and is so widely covered by younger units and obscured by surficial deposits and timber that only general relations could be established.

To the west, the southern margin of the Big John caldera is covered by several younger volcanic accumulations now well exposed in the canyon of Beaver River. Delano Peak Tuff Member is exposed in a small window along Beaver River 12 km southwest of Three Creeks Reservoir. It is overlain by dark, mafic intermediate-composition lava flows and volcanic breccias, with local ash-flow tuffs, that constitute two small relatively young volcanoes in the Mount Dutton assemblage, and these in turn are overlain by thick, coarsely porphyritic, quartz latite lava flows and domes that Sigmund (1979) has called the formation of Lousy Jim (fig. 1, unit Tlj).

Lousy Jim rocks also have been dated by the K-Ar method as about 22 m.y. old (Fleck and others, 1975, p. 56), and thus conceivably could be related to the later parts of the Big John caldera cycle. The location of source vents for the Lousy Jim near the projected margin of the Big John caldera lends credence to this possibility. However, so many volcanic eruptions were taking place within such a brief span of time about 22 m.y. ago that it is difficult to distinguish those that are genetically related.

Also dated (K-Ar) within analytical uncertainty as 22 m.y. old (Fleck and others, 1975, p. 57) is a local shield volcano or lava plateau of potassium-rich basalt or basaltic andesite (fig. 1, unit Tomf) that now forms the crest of Circleville Mountain in the southern part of figure 1. This pile of mafic lava flows filled a broad valley cut in the older Mount Dutton volcanoes. It was derived from local dike sources (fig. 1, unit Tomi), and nowhere is in contact with any of the other volcanic units also dated as about 22 m.y. old.

By 19 m.y. ago the area of the Big John caldera was a broad basin drained through a southward-trending canyon that had been cut across older volcanic rocks south of the caldera. No details of the erosional history that led to cutting of this canyon have been established because most of the evidence has been removed by erosion or covered by younger volcanic units. The lower part of the eroded caldera basin, and at least the upper part of the outlet canyon, was filled to an unknown thickness by stream sands and gravels.

The outlet where the canyon leaves the caldera area is clearly defined on the south side of Lake Stream, 1.5 to 3.0 km east of the Three Creeks Reservoir (fig. 1). The canyon obviously extended southward either east or west of the older basaltic shield volcano or lava plateau underlying Circleville Mountain, but the south end of the channel has not been located yet. The position shown on figure 1 is conjectural.

Postcaldera geology

The drained topographic basin relict from the Big John caldera was just south of the western source area of the Mount Belknap Volcanics (Cunningham and Steven, 1979a), the site of voluminous eruptions of rhyolitic ash and lava flows about 19 m.y. ago. Ash flows from this source area filled the Big John basin with variably welded ash-flow tuffs of the Joe Lott Tuff Member. The degree of welding in the Joe Lott changed markedly outward from the source, and near the outlet of the basin much of the ash was virtually nonwelded. This soft vitric material was largely altered by ground water to the zeolite mineral clinoptilolite; the quality and quantity of the clinoptilolite constitute a potential resource (Steven and Cunningham, 1979b).

Several minor ash-flow units, also derived from the western source area of the Mount Belknap Volcanics, overlie the Joe Lott Tuff Member in the southern part of the Big John caldera (Steven and others, 1979, p. 27).

These, too, were largely nonwelded and also were diagenetically altered to clinoptilolite and clay (Steven and Cunningham, 1979b).

As indicated by present exposures, the soft Mount Belknap Volcanics units extend only 2-3 km down the outlet channel, although they probably extended much farther when originally deposited. This soft material was largely removed when later erosion reexcavated the southward drainage from the Big John caldera area. Not only were the soft Mount Belknap tuff units in the channel eroded, but any older stream sediments that underlay the Mount Belknap were also stripped during this period of erosion.

Later in middle Miocene or younger time, basaltic lava flows were erupted widely in the southern Tushar Mountains and adjacent areas, and mafic gravels, consisting of an estimated 90 percent clasts of the younger basalt and 10 percent clasts of the older basalt from the Circleville Mountain area, were deposited essentially concurrently. Drainage from the Big John caldera was blocked, and the gravel apron back-filled the older channel to the edge of the Mount Belknap rocks that still filled the Big John caldera and upper several kilometers of the outlet channel. The contact between the local stream sediments and overlying Mount Belknap Volcanics that form much of the fill in the Big John caldera, and the younger mafic gravels now occupying most of the outlet channel, is irregularly abutting and is close to the topographic wall of the Big John caldera (fig. 1). This coincidence of rock units of many types and ages meeting within a limited area along steep erosional contacts with opposite inclinations has made a relatively simple sequence of events quite difficult to decipher.

The accumulation of the younger basalt lava flows and related gravels, in combination with widespread Basin-Range faulting and deformation in later Cenozoic times, totally disrupted the earlier drainage system of the Big John caldera. Modern Beaver River and its tributaries now drain westward consequent on the westward-tilted mountain range. The deep canyons cut by this new drainage system are athwart the earlier trends and give cross-sectional exposures that permit reconstruction of the earlier events.

Environments favorable for uranium accumulation

Uranium deposits and occurrences are widespread in the Marysvale volcanic field. These typically are associated with Miocene or younger rhyolites which form the silicic end member of the bimodal basalt-rhyolite association erupted in later Cenozoic time concurrent with regional Basin-Range tectonism. This bimodal association is younger than the Oligocene-early Miocene calc-alkaline volcanic rocks in the Marysvale volcanic field which include the Delano Peak Tuff Member. The most voluminous bimodal rhyolite unit in the Tushar Mountain area is the Mount Belknap Volcanics. In part the uranium is in epigenetic veins, as in the Central mining area north of Marysvale (Cunningham and Steven, 1979b), and in part the uranium occurs dispersed through the rocks or has been leached from the rocks and either redeposited elsewhere or moved in solution into the hydrologic regime (Cunningham and Steven, 1979a). No evidence was seen for epigenetic uranium occurrences in the Big John caldera, but two environments in which remobilized rock-uranium may have been deposited have been recognized.

The stream gravels and sands that accumulated in the lower part of the Big John caldera before eruption of the Mount Belknap Volcanics would seem to represent an excellent potential host for sandstone-type uranium deposits. The sediments were originally relatively permeable and although now somewhat indurated, they still are more permeable than most of the surrounding volcanic rocks. They were covered by uranium-rich ash-flow tuffs of the Mount Belknap Volcanics, which is the chief unit associated with uranium deposits in the

Marysvale volcanic field. Some of these tuffs within the Big John caldera have been diagenetically altered to zeolite and clay and the contained uranium has been partly released from the original glassy ash. Delayed neutron activation analyses of glassy and devitrified Joe Lott Tuff samples indicate that original uranium contents were in the range of 12-18 ppm. Samples of zeolitized Joe Lott Tuff within the Big John caldera contain only 5.4-8.3 ppm uranium, suggesting that about half the original uranium has been lost to the hydrologic regime. In addition, even the more welded rock is completely devitrified so that the uranium originally dispersed through the magma has been moved to discrete crystalline residences where it is susceptible to ground water leaching (Zielinski, 1978).

The stream sediments are exposed in two general areas (fig. 1): one km southwest of Puffer Lake, a section at least 15 m thick underlies the Joe Lott Tuff Member in stream cuts along Lake Stream and along nearby Highway 153; and near Three Creek Reservoir, 4 km farther southwest, a similar thickness underlies the Joe Lott along the same stream and highway. In neither locality is the base of the stream-sediment unit exposed. The area between these two occurrences is completely covered by Joe Lott Tuff Member, as are all adjacent areas within the southern part of the Big John caldera. Of especial interest, the sandstones and conglomerates near Puffer Lake are thoroughly oxidized and typically are stained bright red by hematite. The occurrence near Three Creek Reservoir, which is downstream in the original drainage system near the outlet of the Big John basin, is dull brown in color and shows little evidence of alteration other than normal compaction. An oxidation-reduction front could readily exist in the covered area between these occurrences. In a uranium-rich province such as this, such a front could have uranium deposits associated with it.

Adverse evidence, however, comes from a reconnaissance helium survey made by G. M. Reimer in October 1979 (Reimer, 1979). Measurements of soil gas made along Highway 153 between the two exposures of the stream sediments failed to detect significant helium concentrations. In addition, preliminary measurements of thermoluminescence of samples of the oxidized rock from the eastern area of exposure did not give any positive indication that a uranium-bearing redox roll-front had passed through these rocks (C. S. Spirakis, U.S. Geological Survey, oral commun., 1979). Several alternative explanations can be postulated for the results from both of these techniques, and neither should be considered as definitely negative at the time. Research is continuing in both fields.

The outlet channel that led southward from the Big John caldera provides another potential environment for precipitating uranium from ground water. Except for the first few kilometers outside the Big John caldera, the early postcaldera stream sediments, as well as the overlying ash-flow tuffs of the Mount Belknap Volcanics, were largely stripped from this channel before the younger basalt flows and related mafic gravels were deposited. Two circumstances bearing on the potential for uranium occurrences can be envisaged: (1) If the gravels formed penecontemporaneous alluvial aprons around erupting basalt volcanoes, ground water from the caldera area could still have drained southward through the gravel fill in the channel until the whole surface and subsurface water-flow pattern was disrupted by Basin-Range tectonism in later Cenozoic time. The mafic gravels that back-filled the channel thus may have served as a semiconfined aquifer at least 10 km long in which oxidation-reduction reactions could have taken place, perhaps with attendant precipitation of uranium. (2) On the other hand, if the gravels were derived from a block-faulted terrain caused by concurrent Basin-Range deformation and basaltic volcanism, the ground-water drainage pattern could have been highly disrupted, and might as well have been toward rather than away from the uranium-bearing source area to the north. In this circumstance, the potential for uranium deposits in the filled channel would be low. More field studies should be conducted to determine which of these alternatives is the more likely.

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DESCRIPTION OF MAP UNITS

Ql	MOSTLY LANDSLIDE DEBRIS (QUATERNARY)--Some alluvial and (or) glacial deposits
Tbas	VESICULAR TO APHANITIC DARK-GRAY TO BLACK BASALT (MIOCENE)--Mostly in low-volume lava flows 1-6 m thick and of limited area. Locally interlayered with unit Tmg
Tmg	COARSE FANGLOMERATE WITH CLASTS OF MAFIC LAVAS (MIOCENE)--An estimated 90 percent of the clasts are from unit Tbas; 10 percent or less are from unit Tomf
Tm	MOUNT BELKNAP VOLCANICS, UNDIVIDED (MIOCENE)--Within the source Mount Belknap caldera, the rocks consist of alternating thick units of densely welded ash-flow tuff and rhyolite lava flows. Outside the caldera, most of the rocks are differentially welded ash-flow tuffs with the Joe Lott Tuff Member greatly predominating
Ts	FLUVIATILE SEDIMENTARY ROCKS, LARGELY SANDSTONES AND CONGLOMERATES (MIOCENE)--Fills the lower part of the Big John caldera near its southern margin
Tomf	BASALT OR BASALTIC ANDESITE LAVA FLOWS FORMING AN ERODED LAVA PLATEAU UNDER CIRCLEVILLE MOUNTAIN (MIOCENE)--The rock is a coarse porphyry with 10-15 percent prominent phenocrysts of pyroxene and about 1 percent phenocrysts of plagioclase in an aphanitic to vesicular matrix. Contains 2-3 percent potassium
Tomi	Dike feeders

Td	MOUNT DUTTON FORMATION, UNDIVIDED (MIOCENE AND OLIGOCENE)--Mostly fine grained dark gray porphyries with small pyroxene and plagioclase phenocrysts in a finely granular matrix
Tlj	FORMATION OF LOUSY JIM (SIGMUND, 1979) (MIOCENE)--Quartz latite porphyry lava flows and volcanic domes. Contains conspicuous (1 cm) phenocrysts of sanidine and andesine together with smaller phenocrysts of hornblende, clinopyroxene, biotite, and Fe-Ti oxides in an aphanitic groundmass
	BULLION CANYON VOLCANICS
Tbu	Upper part, undivided (Miocene)--Largely fine grained dark gray lava flows of intermediate composition containing small phenocrysts of plagioclase and clinopyroxene. Contains a few local, small-volume ash-flow tuffs of somewhat more silicic composition
Tbd	Delano Peak Tuff Member (Miocene)--Densely welded crystal-rich quartz latite ash-flow tuff containing phenocrysts of plagioclase (32 percent), hornblende (9 percent), biotite (4 percent), and Fe-Ti oxide minerals (4 percent)
Tb	Middle and lower part, undivided (Miocene and Oligocene)--Largely porphyritic intermediate-composition lava flows and mud-flow breccias. Includes the 27 m.y. old crystal-rich Three Creeks Tuff Member of the Bullion Canyon Volcanics near the middle, and thin wedges of the 22 m.y. old Osiris Tuff near the top

Figure 2 - CORRELATION OF MAP UNITS

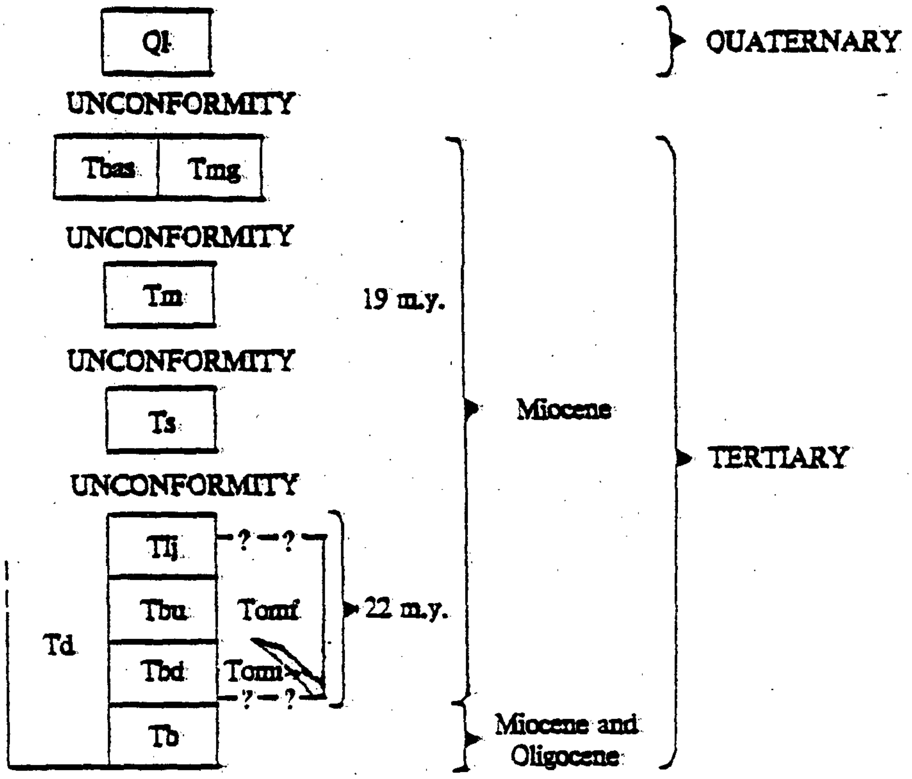

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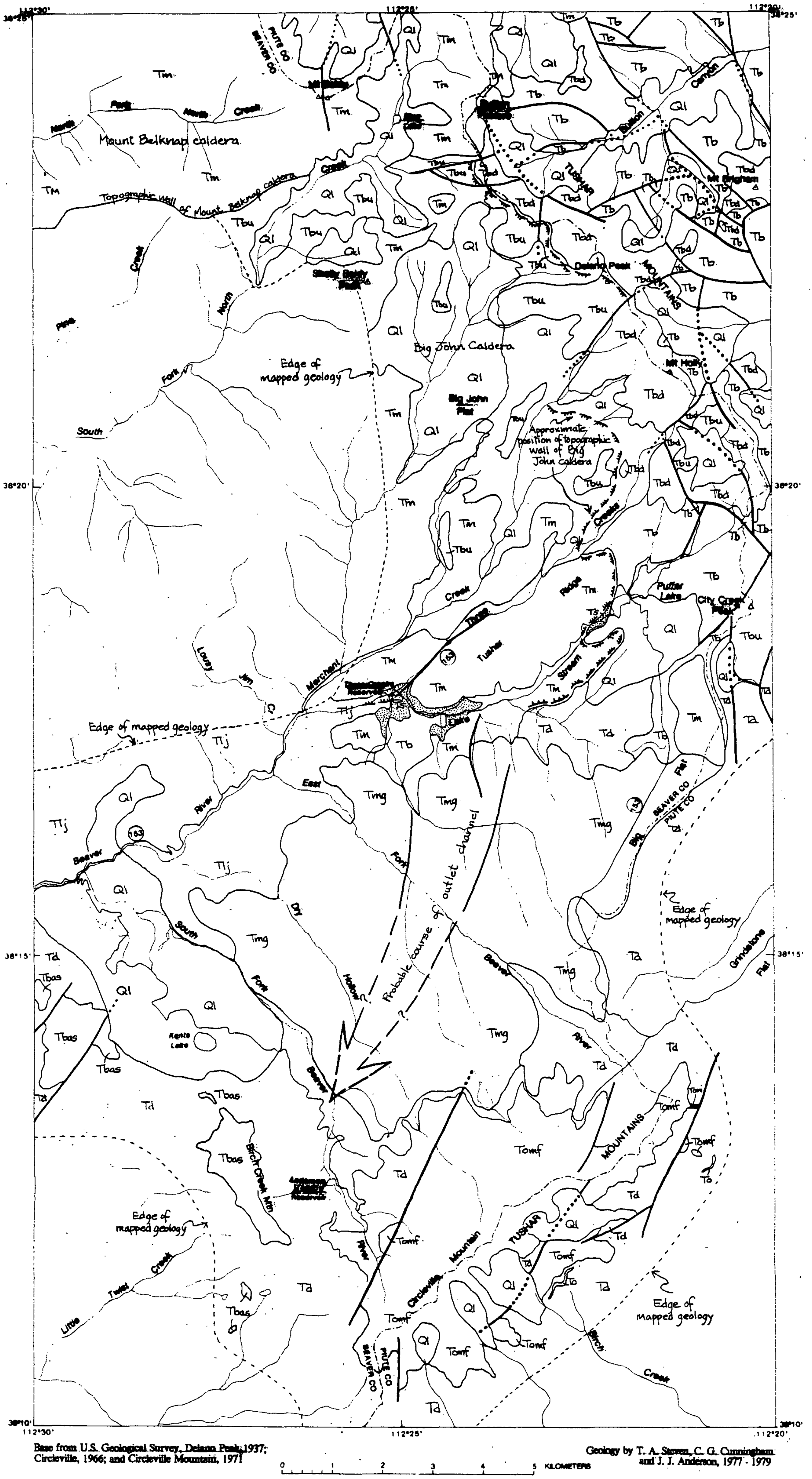
FIGURE 1



Base from U.S. Geological Survey, Delano Peak, 1937; Circleville, 1966; and Circleville Mountain, 1971

Geology by T. A. Steven, C. G. Cunningham and J. J. Anderson, 1977 - 1979

FIG. 1 GEOLOGIC SKETCH MAP OF PART OF THE BIG JOHN CALDERA AND ADJACENT AREAS