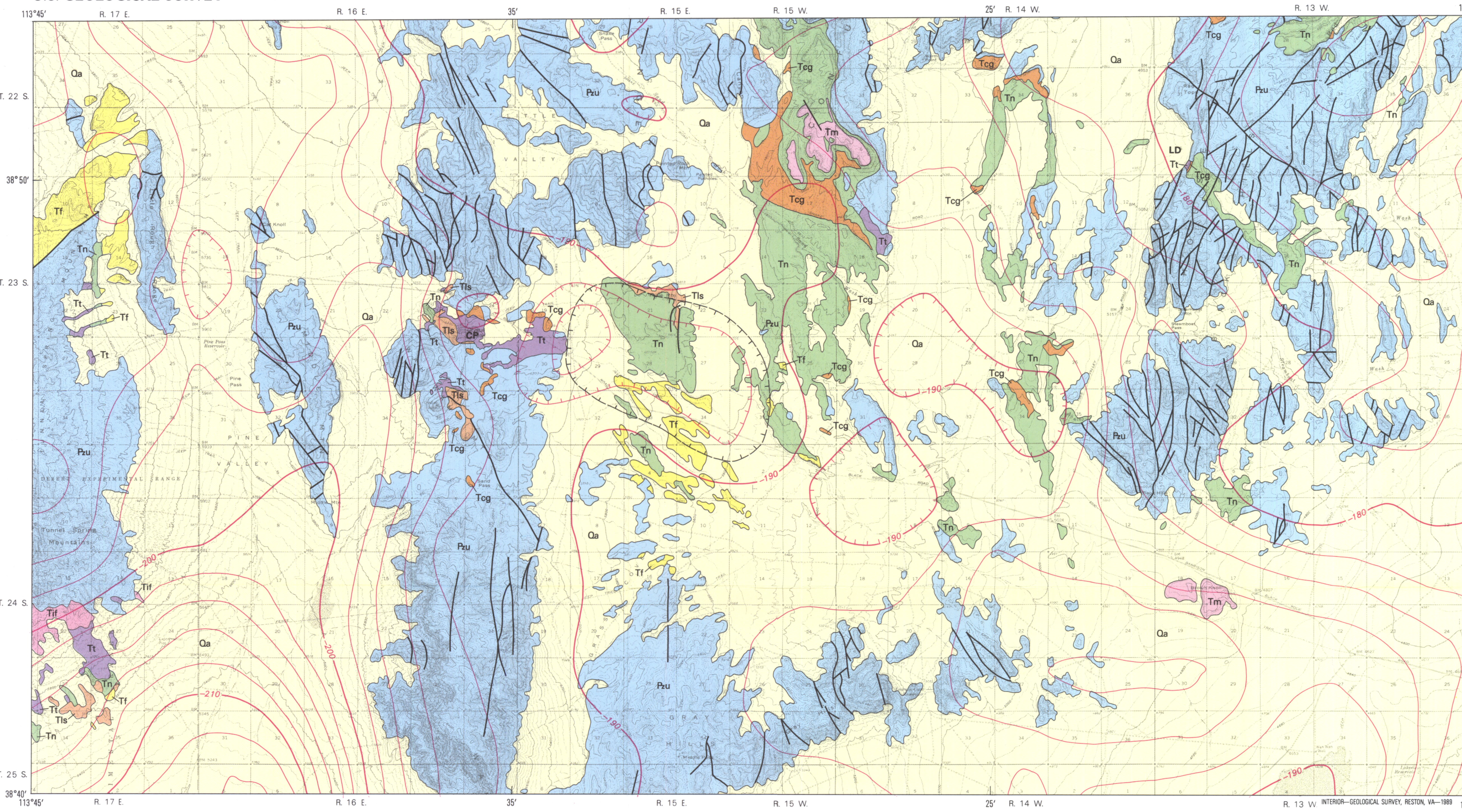


Base from U.S. Geological Survey 1:48,000
Crystal Peak, Frisco Peak, The Barn, and
Wah Wah Summit, 1960

14°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1989

SCALE 1:100 000

1 ½ 0 1 2 3 4 5 MILES

1 .5 0 1 2 3 4 5 KILOMETERS

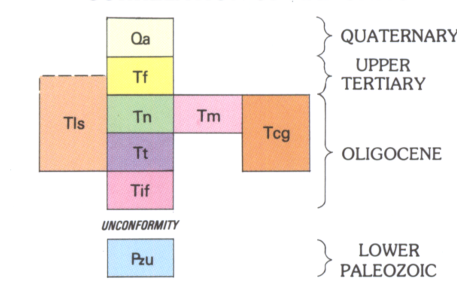
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTAH
MAP LOCATION

Geology modified from Hintze (1974a,b,c) and Hintze and others (1984). Tertiary rocks in part remapped by Steven, 1981–83

Manuscript approved for publication, June 22, 1988

CORRELATION OF MAP UNITS



LIST OF MAP UNITS

Qa	Alluvium (Quaternary)
Tf	Fanglomerate (upper Tertiary)
Tls	Landslide deposits (upper Tertiary(?) to Oligocene)
Tn	Cottonwood Wash Tuff and Wah Wah Springs Formation, undivided (Oligocene)
Tm	Mafic lava flows (Oligocene)
Tcg	Stream gravels (Oligocene)
Tt	Tunnel Spring Tuff (Oligocene)
Tif	Dark-gray to black, intermediate-composition lava flows and volcanic breccia (Oligocene)
Pzu	Sedimentary rocks, undivided (lower Paleozoic)

Contact

Fault

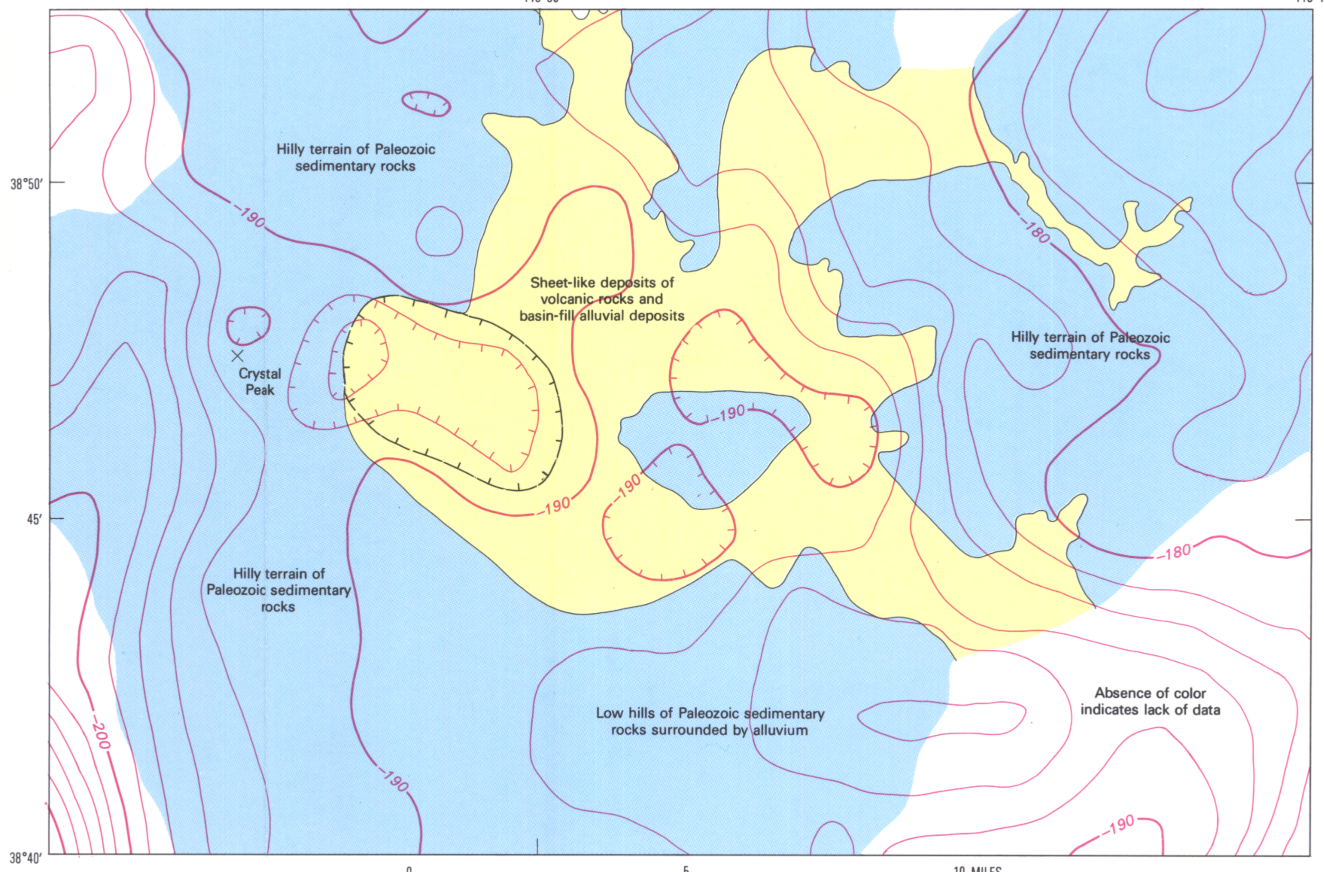
Crystal Peak caldera structural margin—Approximately located

Gravity contour—Hachures indicate closed lows. Contour interval 2 mGal

-200

CP Crystal Peak

LD Lava Dome



0 5 10 MILES

0 5 10 15 KILOMETERS

EXPLANATION

Crystal Peak caldera structural margin—Approximately located

-190 Gravity contour—Hachures indicate closed lows. Contour interval 2 mGal

× Crystal Peak

Figure 1.—Map showing generalized distribution of Paleozoic sedimentary rocks and Tertiary basin-fill deposits with respect to gravity contours and Crystal Peak caldera.

INTRODUCTION

Crystal Peak is a prominent landmark in the sparsely populated mountainous desert of west-central Utah. Its stark-white slopes contrast boldly with the drab dark-gray limestone hills that surround it, and draw the attention and pique the curiosity of travelers of back roads who pass nearby. Despite its bold appearance, Crystal Peak is not an isolated topographic feature; rather it is a distinctive remnant of massive, slightly welded to nonwelded rhyolite ash-flow tuff (the Tunnel Spring Tuff) that once filled a deep canyon cut in Paleozoic strata. It is comparable in altitude with the adjacent mountainous area, but seems isolated because of its distinctive color and composition.

The studies reported here indicate that the Tunnel Spring Tuff was derived from a source located just east of Crystal Peak. Eruptions of pyroclastic material from this source probably led to subsidence of much of the topographic basin east of Crystal Peak now floored by younger ash-flow tuff. Subsidence appears to have been compound, with an oval-shaped deeply subsided block forming the western part of the basin, and a broader, less well defined and less deeply subsided block making up the remainder. Steep, fault-bounded margins can be postulated only for the western block, and for convenience in discussion, the term Crystal Peak caldera will be restricted to this area. The remainder of the subsided area will be referred to more generally as a topographic or subsided basin.

ACKNOWLEDGMENTS

The present investigation grew out of a mineral resource appraisal of the Richfield, Utah, 1°× 2° quadrangle, conducted by the USGS (U.S. Geological Survey) as part of CUSMAP (Conterminous United States Mineral Assessment Program) (Steven and Morris, 1984, 1987). It presents a new interpretation for part of an area already mapped in considerable detail by others. Little change has been made in the geology already published by L.F. Hintze (1974a, b, c; Hintze and others, 1984) except that the volcanic rocks were reexamined, in part remapped, and were extensively reinterpreted. Mr. Hintze has consulted freely with me, and I thank him heartily for his help and encouragement. Thanks also are due to M.G. Best, who visited the area with me and confirmed correlations of ash-flow tuff units. D.L. Campbell of the USGS gave valued council on interpretation of the gravity data. The U.S. Forest Service made facilities at the Desert Range Experiment Station available during part of the study.

GEOLOGIC SETTING

The general setting of Crystal Peak as shown on the geologic map is modified from published geologic maps of the Crystal Peak (Hintze, 1974a), The Barn (Hintze, 1974b), Wah Wah Summit (Hintze, 1974c), and Frisco Peak (Hintze and others, 1984) 15–minute quadrangles. Paleozoic sedimentary rocks, largely early Paleozoic carbonate strata with some interbedded quartzite and shale, are shown as a single unit because they served chiefly as a context for younger igneous events that took place during the middle Tertiary.

In early Oligocene time (about 35 Ma) the gently dipping sedimentary rocks formed a somewhat dissected plateau, with a few deep (as much as 400 m), steep-walled canyons in the central part of the map area, but with more widespread surfaces of low relief to the east and west. About 35 Ma, scattered volcanoes began to erupt in this part of Utah, and two of the vent areas are within the map area: dark-gray to black intermediate-composition lava flows and volcanic breccia, followed by more silicic lava flows and volcanic domes, were erupted near the southwest corner of the map area, and the area just east of Crystal Peak was the site of violent pyroclastic eruptions of moderate magnitude. The pyroclastic debris that spread from the Crystal Peak center has been called the Tunnel Spring Tuff (Bushman, 1973), and it and the caldera that formed at its source are the main subjects of this report.

Later in the Oligocene, about 30–29 Ma, two separate pulses of pyroclastic activity in the Needle Range, 50–80 km south-southwest of Crystal Peak (Best and Grant, 1987), spread voluminous ash flows northward into the map area to deposit the Cottonwood Wash Tuff and Wah Wah Springs Formation of the Needles Range Group. These formations form nearly continuous sheets across the subsided area at the Crystal Peak volcanic center (map), but were more locally distributed in canyons and across local areas of low relief elsewhere. Alluvial gravel and sparse mafic lava flows of local derivation are interlayered with ash-flow tuff sheets of the Needles Range Group in the lower part of the basin fill, and later fanglomerate deposits formed the upper part of the fill.

The sedimentary and volcanic units were disrupted by north- to northwest-trending normal faults in late Cenozoic time as the result of extensional basin-range tectonism, which divided the area into horst and graben blocks. The downfaulted troughs that resulted are filled to various depths by alluvial and playa lake deposits. The layered Paleozoic rocks are still broadly flat lying across the central part of the map area, but those in the eastern part dip gently 5–7° eastward toward the basin occupied by Sevier Lake 2–15 km distant.

THE TUNNEL SPRING TUFF

The Tunnel Spring Tuff is more than 400 m thick under Crystal Peak, where it filled a deep canyon cut in the preexisting terrain. Elsewhere, small scraps of Tunnel Spring Tuff have been mapped as much as 25 km east and 15–25 km west and southwest of Crystal Peak, but in most of these places the unit does not exceed a few tens of meters in thickness. An exception is at Cowboy Pass, 13 km west of Crystal Peak, where Bushman (1973, p. 180) reported 570 m of bedded (reworked?) Tunnel Spring Tuff. A common presumption has been, therefore, that Crystal Peak is near the source of the Tunnel Spring Tuff, and this presumption has received support from data collected during this study.

As reported by Hintze (1974a, quoting R.L. Armstrong, written commun., 1970) the Tunnel Spring Tuff was erupted about 33 Ma (not recalculated according to more recent K-Ar decay constants), and the Wah Wah Springs Formation has been dated as 29.5 Ma according to Best and Grant (1987). These ages have been corroborated in general by samples submitted in connection with this investigation; using the K-Ar method, H.H. Mehnert of the USGS (written commun., 1982) determined an age of about 35.4 Ma for the Tunnel Spring Tuff, and 28.4 Ma for the younger Wah Wah Springs Formation. The lack of precise concordance between these ages is not important to this study.

The lower part of the Tunnel Spring Tuff, which makes up all of Crystal Peak and scattered remnants to the west, is a massive, slightly welded to nonwelded rhyolite ash-flow tuff that consists of 27 percent phenocrysts (Bushman, 1973) of distinctive doubly terminated quartz crystals, glassy feldspar tablets, and sparse biotite flakes set in a white glassy ash matrix. The quartz phenocrysts in particular are responsible for the geographic name Crystal Peak. Cognate pumice and lava fragments are significant constituents as are fragments of limestone and quartzite from the underlying Paleozoic sedimentary rocks.

More than 400 m of lower Tunnel Spring ash-flow tuff are exposed on the bare slopes of Crystal Peak without evidence of any break in the eruption. Slight local variations in weathering characteristics and abundance of fragments indicate some variation in eruptive intensity, but no bedding plane was observed within the main mass of tuff that might indicate a break in the eruption itself. Bushman (1973, p. 176) noted bedding at three places in the Tunnel Spring, but all those places shown on his map are near the margins of the filled paleovalley at Crystal Peak. The remnant of massive tuff underlying Crystal Peak extends for 5 km along the ancient canyon that encloses it. The foreign sedimentary rock fragments within the tuff range in abundance and size from an estimated less than 10 percent and sand to small gravel size at the west end of exposure, to 30–40 percent and angular fragments as much as 30 cm across at the east end of exposure. Cognate pumice and lava fragments are even more impressive, ranging from small lapilli on the west to large blocks as much as 0.6 m across at the east end of exposure. Bushman (1973) also noted this distribution in size of rock fragments.

These described lateral variations in a single thick accumulation of slightly welded tuff are interpreted to reflect winnowing within a vertical column of continuously erupted ash in which the larger and heavier fragments fell nearest the source and progressively finer and lighter fragments farther away. The extremely thick accumulation of massive tuff at Crystal Peak in contrast with the much thinner distal deposits indicates that the ash cloud collapsed largely vertically and that only the outer parts with finer and more sparse cognate and foreign fragments spread widely as ash flows. These ash flows spread largely westward, whether for topographic reasons or under the influence of some other undetermined factor.

The upper part of the Tunnel Spring Tuff is exposed in an area 8–12 km east-northeast of Crystal Peak, where several bedded units overlie a massive, pumice-rich, nonwelded rhyolite tuff containing abundant phenocrysts, including quartz. This basal unit is believed equivalent to the massive lower part of the Tunnel Spring Tuff underlying Crystal Peak. Overlying deposits range from one massive, pink to white, poorly welded ash-flow tuff sheet containing only a few percent quartz and feldspar phenocrysts and fine biotite phenocrysts, to bedded air-fall tuff, and to granular, bedded to crossbedded surge deposits from which much of the finer ash has been winnowed. Exposures are too poor for a complete section to be described. Some exposures of the massive, pink ash-flow tuff as much as 20 m thick have been observed, but generally it is thinner. The thickest accumulation (about 20 m) was seen at the Lava Dam location (10 km southwest of the northeast corner of the map area) where it was confined to the base of a narrow canyon. Many individual eruptions are clearly indicated by the upper units in the Tunnel Spring, but none seems to have had significant volume.

ANCIENT LANDSLIDE DEPOSITS

Hintze (1972, 1974a,b,c) has documented the occurrence of ancient landslides in west-central Utah in the general vicinity of the map area. Although in his map explanations Hintze shows these deposits as occurring at a specific place in the stratigraphic succession between the Tunnel Spring Tuff and the Cottonwood Wash Tuff, data presented here indicate that they formed at several different times. On his map of the Crystal Peak quadrangle (Hintze, 1974a), landslide deposits in the conglomerate of Skull Rock Pass locally mantle the southern flank of the paleocanyon that contains the Tunnel Spring Tuff at Crystal Peak and clearly underlie that unit. Landslide or coarse alluvial deposits of a younger age were identified during the present investigation along the north side of Table Mountain, 5–6.5 km east-northeast of Crystal Peak; these deposits consist of unsorted boulders of mixed Paleozoic sedimentary rock types as much as several meters across, and are interleaved between Cottonwood Wash Tuff and Wah Wah Springs Formation in the fill of the Crystal Peak caldera. A still younger coarse alluvial or paleolandslide was mapped by both Hintze (1974c) and Bushman (1973) and restudied by me near the southwest corner of the area shown on the map. These bouldery deposits cover a fault that juxtaposes tilted rocks of Cottonwood Wash Tuff and Wah Wah Springs Formation; this fault is typical of the late Cenozoic basin-range faults that cut sedimentary and volcanic rocks of western Utah, so the younger landslide deposits also are probably of late Cenozoic age.

Only the coarse deposits interleaved between Cottonwood Wash Tuff and Wah Wah Springs Formation 5–6.5 km east-northeast of Crystal Peak are relevant to the geologic story being told here. As will be detailed later, these intra-Needles Range Group deposits probably were derived from an oversteepened caldera wall and were deposited within caldera-fill ash-flow tuff units derived from distant sources.

CALDERA-FILL DEPOSITS

By middle Oligocene time, what had been a dissected plateau area in the early Oligocene had gone through a topographic reversal, and had become an irregular basin about 16 km long east-west and 10 km wide north-south (map and fig. 1). This basin localized deposition of a mixed assemblage of locally derived gravel, ash-flow tuff from distant sources, and local colluvial deposits possibly including landslides. The regional ash-flow units formed nearly continuous sheets within the depression, whereas in adjacent areas they formed tongue-like bodies confined to the lower parts of a hilly topography.

The lower part of the basin fill is nowhere exposed, and it has not been possible to determine what the thickness or distribution of the buried Tunnel Spring Tuff may be. A significant volume could be present within a local, apparently more deeply subsided block in the western part of the basin (the caldera, as shown on the map and fig. 1), but much less is permissible beneath the eastern two-thirds where erosion has bared the tops of several local hills of Paleozoic sedimentary rocks that protrude up into the basin fill.

When the formations of the Needles Range Group were erupted in middle Oligocene time from sources many kilometers to the south (Best and Grant, 1987), the subsided basin east of Crystal Peak was receiving abundant gravel from the adjacent sedimentary terrain. Most of the exposed gravels were supplied through a deep canyon that entered the basin from the north, and were deposited as alluvial fans. Ash flows from the south deposited the Cottonwood Wash Tuff northward across the basin to wedge out against these fans as well as the steep slopes of Paleozoic sedimentary rocks bounding the north side of the subsided basin. The degree of welding of the Cottonwood Wash rocks drops off markedly near the wedge-outs. The Cottonwood Wash Tuff within the basin is not anomalously thick as compared to adjacent areas in western Utah, indicating that the underlying gravels had already filled the deeper parts of the depression. The Cottonwood Wash Tuff within the basin contains abundant sedimentary rock fragments presumably picked up from the underlying gravel deposits. In a few places, the basal few feet of the Cottonwood Wash Tuff contains a bed load of exceptionally abundant sedimentary fragments, an observation in support of this suggestion. Many of the limestone fragments within the Cottonwood Wash Tuff show marked reaction rims against the adjacent once-hot welded tuff.

Gravels continued to be deposited as alluvial fans out into the basin after the Cottonwood Wash Tuff accumulated. These gravels formed irregular tongues as much as 40 m thick near the mouth of the feeder canyon, but range widely in thickness from a featheredge to 10 m or more where exposed at the edges of local fault blocks out within the basin. In cross section, these tongues appear as lenses between the sheets of welded tuff. Pre-Cottonwood Wash gravels merge with post-Cottonwood Wash gravels in places near the mouth of the feeder canyon. Obviously emplacement of the Cottonwood Wash Tuff sheet resulted from an external event that interrupted but did not stop deposition of locally derived gravels in the basin.

In places, the stream gravel deposits above the Cottonwood Wash Tuff seem to contain abundant large angular fragments of Paleozoic rocks as much as a meter across. Mostly these now appear as scattered lag blocks strewn across gravelly surfaces. In one place along the north side of Table Mountain 5–6.5 km east-northeast of Crystal Peak, however, the blocks form a discrete body of mixed sedimentary rock types that wedges out basinward where it is replaced by a layer of stream gravels. The wedge is interpreted to be an ancient landslide mass that caved off a steep slope that existed along the north side of the topographic basin in middle Oligocene time.

Several mafic, scoriaceous to dense, fine-grained lava flows from local but unknown sources accumulated on top of the Cottonwood Wash Tuff near the mouth of the feeder canyon north of the basin. Although the equivalent stratigraphic position nearby is occupied by gravels, no gravels are present either beneath or above the mafic flows. This suggests that the mafic lavas were erupted very soon after the Cottonwood Wash accumulated, and that the flows stood high enough to divert the gravel-bearing streams elsewhere.

The Wah Wah Springs Formation of the Needles Range Group was extremely voluminous and covered a very wide area of western Utah in middle Oligocene time (Best and Grant, 1987). In the area of concern here, it covered the floor of the topographic basin east of Crystal Peak and spread northward for many kilometers across the distal edge of the Cottonwood Wash Tuff. The Wah Wah Springs Formation formed tongues confined to valleys in the underlying terrain everywhere in this vicinity except in the subsided basin east of Crystal Peak where it formed an unbroken sheet. Except for local poorly welded zones near the base, the Wah Wah Springs rocks are generally densely welded, and are exceptionally rich in sedimentary rock fragments within the topographic basin. The source of these fragments is believed to be gravels spread out on top of the Cottonwood Wash Tuff. Reaction rims on limestone fragments are especially apparent within the Wah Wah Springs welded tuffs. The mineralogy of the reaction rims apparently has never been studied.

The Wah Wah Springs Formation is overlain along the south side of the basin by a poorly exposed accumulation of soft fanglomerate with huge boulders of Paleozoic rocks a meter or more across set in a poorly sorted and poorly consolidated matrix. This unit is well defined in places, but mostly is so similar to the modern alluvium that surrounds it that it cannot be mapped separately with confidence. The bouldery fanglomerate seems to represent largely mud-flow deposits that covered the ash-flow tuff sheets of the Needles Range Group in the topographic basin some time in late Tertiary time, only to be largely reexcavated by the erosion that cut the present topography and deposited the more recent alluvial deposits. Exposures are too poor to tell whether the basin-range faults which so clearly cut the Wah Wah Springs Formation are either older or younger than the fanglomerate.

CALDERA SUBSIDENCE

Subsidence related to climactic eruption of the lower part of the Tunnel Spring Tuff is indicated by a number of lines of evidence. The source area of the lower Tunnel Spring east of Crystal Peak, as indicated by lateral variations in size and abundance of fragments, totally disappeared by the time the next major rock unit, the Cottonwood Wash Tuff, accumulated in middle Oligocene time. Lower Tunnel Spring rocks making up Crystal Peak end abruptly eastward at a point along a concave-eastward arc that marks the eastern edge of Paleozoic sedimentary rocks adjacent to a topographic basin that clearly was in existence in middle Oligocene time. This topographic basin formed suddenly in early Oligocene time in an area that previously was a dissected highland. Stream gravels derived from the surrounding highlands were carried to and deposited within this basin before, during, and after emplacement of the ash-flow tuff sheets of the Needles Range Group, and chaotic landslide masses slid from oversteepened marginal walls along the north and west sides of the basin during the same interval. Finally, the lithology of the massive lower Tunnel Spring rocks indicates a type of pyroclastic eruption that commonly results in rapid evacuation of the upper part of the source magma chamber with attendant collapse of the overlying rocks.

As conjectured from indirect evidence, the subsided basin east of Crystal Peak seems to have had a complex history of development. The western one-third of the basin is interpreted to be a sharply defined and probably fault-bounded block 6.5 km long east-west and 4 km wide north-south (map and fig. 1). The western wall of this block is sharp and closely constrained by the abrupt eastward cutoff of lower Tunnel Spring rocks and adjacent Paleozoic sedimentary rocks along an arcuate, concave-eastward front. This sharp cutoff probably reflects a faulted margin on the subsided block. Gravity data (map and fig. 1; see also next section for discussion) suggest that the adjacent deeply subsided part of the basin may be underlain by a significant thickness of low-density fill, perhaps equivalent to the thickness of Tunnel Spring Tuff now exposed on the nearby flanks of Crystal Peak. The deepest part of the gravity low ends eastward about where two small areas of exposed Paleozoic rocks indicate that a relatively shallow bedrock floor exists beneath the basin fill. The postulated margin of the caldera is drawn just west of these areas of exposure, in the middle of the gradient marking the eastern end of the deepest gravity low.

In contrast, the eastern two-thirds of the basin is broader and more irregularly shaped, and does not appear to have subsided as deeply as the western part. Locally exposed tops of buried hills of Paleozoic sedimentary rocks in the eastern part of the basin suggest that an irregular (hilly) floor beneath caldera fill exists here at relatively shallow depths. Prior to subsidence in early Oligocene time, this buried terrain probably was at or above the levels of the tops of adjacent modern hills flanking the basin. The locations of specific structures bounding the eastern part of the depression are poorly constrained and their character, if present, is not known. The postulated deep floor under caldera fill in the western part of the basin, and relatively shallow depth to the floor in the eastern part, suggest complex subsidence that may have involved faulting in places and warping or tilting in others. It seems unlikely that the whole basin area subsided as a unit, nor even at the same time. If the interpretation is valid that a thick fill of Tunnel Spring Tuff exists in the western part of the basin, but is largely absent in the eastern part, development of the two parts could have been sequential.

The exposed walls of the caldera were modified significantly following subsidence. Landslides off the oversteepened walls have been recognized in the caldera fill along the northwestern margin of the caldera, and stream erosion elsewhere cut into the walls and carried gravels into the depression. The stream erosion in particular enlarged the topographic basin in places, and permitted the subsequent Needles Range Group ash flows to extend outward as tongues from the more nearly continuous sheets deposited within the basin (map). All these younger rocks effectively cover and obscure the structures responsible for forming the depression.

GRAVITY EXPRESSION

The middle Tertiary topographic basin east of Crystal Peak that was covered by sheet-like layers of Cottonwood Wash Tuff and Wah Wah Spring Formation coincides with a pronounced Bouguer gravity low that measures roughly 18 km by 10 km (map and fig. 1). These gravity contours were taken from Cox and others (in press, fig. 4), who in turn obtained their data from an unpublished regional gravity map being prepared by Viki Bankey, USGS, under the direction of Kenneth L. Cook, University of Utah. The overall low consists of two unequal parts: a deep western low that corresponds largely to the area of the Crystal Peak caldera as constrained by geologic data, and an eastern low that forms a broad undulating gravity shelf beneath the eastern part of the subsided basin. Partly exhumed paleohills of Paleozoic sedimentary rocks still more or less covered by veneers of volcanic rocks are exposed throughout the area of the gravity shelf.

Specific density data for rocks in the Crystal Peak area are largely lacking, and the gravity anomalies shown on the map and figure 1 can be discussed only in general, qualitative terms. Most of the Tunnel Spring Tuff is poorly compacted and porous, and contains abundant fragments of uncollapsed pumice. Lithic fragments of cognate lava and sedimentary rock types, however, commonly are abundant and add to the density of the rock. Much of this material probably has a density of 2.0 g/cm³ or less. The Tunnel Spring Tuff contains abundant quartz phenocrysts and sparse biotite, and is obviously silicic in composition. The crystallized equivalent rock that congealed in the source magma chamber at depth should be granitic or granodioritic in composition, with density possibly in the range of 2.6–2.65 g/cm³. Wall rocks adjacent to this congealed magma chamber (pluton) are not known. Most likely they consist of compact quartzites, limestones, and dolomites in the lower part of the sedimentary section, or of Proterozoic gneisses in the underlying basement; in either case, the general densities are possibly in the range of 2.65–2.75 g/cm³. However accurate these estimates may be, it seems likely that major density contrasts exist between surface accumulations of Tunnel Spring Tuff and bedrock units, and that contrasts within the bedrock are much less.

The deep western part of overall gravity low just east of Crystal Peak not only embraces the area of the Crystal Peak caldera (map and fig. 1), but it extends about 1.5 km west of the western boundary of the caldera as indicated by surface geology. The deepest part of the low (<−194 mGal) underlies this boundary and clearly extends west of the caldera area. The western, northern, and southern boundaries of this deep low are marked by sharp gradients, reflecting steep boundaries on the lower density rock body or bodies that cause the low; the gradient to the east is somewhat gentler, indicating that a less sharp (or more gently inclined) boundary on the lower density body exists in this direction. Some of the deep gravity low marking this western lobe probably reflects a prism of low-density tuff filling the caldera that formed in response to eruption of the Tunnel Spring Tuff; this material probably is similar to the nonwelded to slightly welded tuff underlying Crystal Peak, although some may be gravel or landslide breccias derived from the caldera walls. This material should be at least as thick as the Tunnel Spring Tuff exposed just to the west under Crystal Peak (about 400 m). Such low-density material cannot account for that part of the deep low that extends west of the caldera area, however, and this more likely reflects a shallow intrusion that served as a source magma chamber for the Tunnel Spring Tuff. This intrusion probably has a silicic composition, whose density would contrast somewhat with the denser Paleozoic sedimentary rocks or Proterozoic gneisses enclosing it. The sharp bounding gravity gradients on the north, west, and south sides of the western lobe thus probably reflect steep (possibly near vertical) walls of this intrusion. The more gentle gradient on the east side of the deep low will be discussed in the next paragraph in the context of the gravity shelf located east of the caldera area.

East of its deep western part, the gravity low expands to form a broad undulating gravity shelf. Even though the eastern shelf area is broader than the western part, it is not as deep (averaging about −190 mGal over much of its extent). The tops of scattered hills of sedimentary rock extend up into the volcanic fill of the eastern lobe, and suggest that near-surface volcanic or alluvial fill is nowhere thick enough to account for much of the negative mass anomaly. In addition, the gravity contours, though quite well controlled by nearby gravity stations (Viki Bankey, unpub. data) are relatively insensitive to the surface distribution of volcanic versus sedimentary rocks, suggesting that this factor only in part controls the gravity configuration. More likely the anomaly reflects a deeper source, possibly an eastward continuation of the silicic pluton postulated to underlie the caldera area. A sharp (about 10 mGal over 3 km) marginal gradient along the eastern edge of the shelf suggests a steep wall on the postulated pluton in this direction. The gradient between the deep western low and the shelf probably reflects in part the eastern margin of the light fill in the Crystal Peak caldera, and in part the influence of a plate of relatively dense sedimentary rocks between the base of the basin fill in the gravity shelf area and the top of the underlying pluton. The northern and southern margins of the broad gravity shelf are not closely defined, suggesting perhaps less steeply inclined margins on the postulated pluton in these directions.

BASIN-RANGE FAULTING

Bedrock in the Crystal Peak area is riven by late Cenozoic faults, and the distribution of the present mountains and basins has resulted largely from major block faulting. Geomorphic evidence suggests that the faulting extended over a significant span of time, inasmuch as some mountain fronts are frayed by erosion and flanked by well-developed alluvial fans, whereas others are steep and linear and have only minor fans built in front of small gullies. Previous geologic maps (Hintze, 1974a, b) suggested that the volcanic rocks were less affected by faulting than adjacent Paleozoic sedimentary rocks, but our remapping of the volcanic rocks shows that these too have been extensively broken, in part by faults that project into the basin from the adjacent sedimentary terrane. However, the sheet-like layers of Needles Range rocks do seem somewhat less broken than the surrounding sedimentary rocks, which may reflect a strengthening of the caldera area by a shallow underlying pluton which acted as a buttress.

SUMMARY

In early Oligocene time, an area 16 km by 10 km across just east of Crystal Peak was suddenly converted from a dissected plateau to a steep-walled topographic basin. This change coincided with eruption of the lower part of the Tunnel Spring Tuff, and is believed to have resulted from subsidence of the source area of the Tunnel Spring, as violent pyroclastic eruptions emptied the top of the underlying magma chamber. Subsidence was complex and is not well understood. The western part of the basin seems underlain by an oval-shaped block (a caldera) that is at least in part and perhaps entirely bounded by steep walls, and may contain a significant thickness of low-density tuffaceous fill. The eastern part of the basin is less deeply subsided, and contains thinner and more irregularly distributed fill. Subsidence in the eastern part of the basin may have been in part by tilting and warping.

The gravity low that closely mirrors the area of subsidence indicated by geologic data locally extends outside closely constrained geologic boundaries of subsidence. This indicates that near-surface low-density fill can only in part account for the measured gravity configuration. An underlying silicic pluton that served as a source for the Tunnel Spring Tuff is believed responsible for much of the gravity low. The broad, undulating low in the eastern part of the subsided basin is interpreted to reflect largely the influence of this underlying pluton, whereas the deeper oval-shaped low in the western part of the basin reflects both the underlying pluton and a local tuff-filled caldera block that collapsed around the eruptive vent.

Immediately after subsidence, the basin began to accumulate debris that slid off or was washed from adjacent highlands; some of this debris formed landslides and some was gravel deposited by streams. In middle Oligocene time, two major ash-flow formations of the Needles Range Group, derived from sources far to the south, invaded the area of the Crystal Peak caldera. These ash flows were channeled by stream valleys in the hilly area around the basin, but formed coherent sheets within the subsided basin where they interlayered with gravels of local derivation. Locally derived mafic lava flows also accumulated in the caldera area at about the same time. Later in the Tertiary, the partly filled subsided basin was covered to an unknown depth by fanglomerate deposits, was broken by regional basin-range faulting, and was eroded to the present terrain of north- to northwest-trending fault block mountains separated by partly alluviated structural troughs. Detailed chronology of these latter events has not been established.

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GEOLOGIC MAP OF THE CRYSTAL PEAK CALDERA, WEST-CENTRAL UTAH

By
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