GEOLOGIC MAP OF THE COPPER CREEK BENCHES QUADRANGLE, GARFIELD COUNTY, UTAH

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INTRODUCTION

The Copper Creek Benches quadrangle lies in the southern Henry Mountains, about 15 mi (25 km) north of Lake Powell, in southeastern Utah. The southern flank of Mount Hillers, the northwestern flank of Mount Ellsworth and the nearly flat-lying sedimentary host rocks surrounding these two igneous domes (Fig. 1) are exposed within the map area (Plate 1).

The Henry Mountains are one of several mountain ranges on the Colorado Plateau that are composed of domed sedimentary rocks with igneous cores, and surrounded by dikes, sills, small laccoliths, and bysmaliths. The north-trending range formed of the Henry Mountains is about 60 km long, and is composed of 5 peaks separated by low passes. These mountains lie within the gently-dipping eastern limb of the north-south trending Henry structural basin that is bounded on the west by the Waterpocket Monocline (Hunt, 1953, Plate 1), and that formed during Laramide time. Sedimentary rocks were deposited during the Late Proterozoic, Paleozoic and Mesozoic Eras. The oldest rocks exposed in the range are Permian in age. Potassium-argon ages of intrusions of diorite porphyry exposed in the Henry Mountains at Bull Mountain and Mount Hillers are 44 to 48 Ma (Armstrong, 1969). Fission track methods, however, give ages of 20-29 Ma (Sullivan, 1987).

G. K. Gilbert (1877) originated the concept of laccolithic intrusions based on his observations of small, floored intrusions exposed on the flanks of the Henry Mountain domes. Gilbert hypothesized that these intrusions were fed from below by a dike or pipe-like conduit and grew from a thin sill by lifting and bending of a largely concordant overburden (Fig. 2); he suggested that the large domes are direct analogues of these smaller intrusions. More recently, C. B. Hunt (1953) mapped the Henry Mountains region, using an alidade, plane table and triangulation net, because topographic base maps were not available in the 1930's. Hunt inferred that the central intrusions forming the domes are cylindrical stocks, sheathed in a zone of shattered sedimentary rocks (Fig. 3). He believed that the small sills and laccoliths on the flanks of the domes grew laterally from the discordant sides of these stocks.

From his work in the Henry Mountains, Gilbert (1877) also described how the processes of lateral planation and the instability of divides contribute to the formation of the piedmont, which is a broad alluvial plain that extends for several kilometers away from the base of each of the igneous domes. Lateral planation is a process by which a meandering stream erodes its banks, forming a broad flood plain. Stream diversion, where a stream abandons its channel for a new course, enhances this process. Through time, these two processes allow the streams of the Henry Mountains to erode broad pediments, leaving behind a thin veneer of gravels on these surfaces. Hunt (1953) mapped the Quaternary geology and geomorphology of the Henry Mountains in greater detail. Expanding on Gilbert's ideas, Hunt (1953) emphasized the importance of stream capture or diversion in piedmont development in the Henry Mountains. Hunt (1953, plate 21) described a process in which streams issuing from the mountains are progressively captured by streams that originate in the piedmont itself. The streams are entrenched below their former courses and they leave behind a number of levels of pediments.

The purpose of our mapping is to introduce new evidence that bears on the laccolith-stock controversy and on the origins of epizonal magma chambers (see Jackson and Pollard, 1988). Our mapping also shows the importance of landsliding on the flanks of the Mount Hillers and Mount Ellsworth domes. Most of the geology was mapped on aerial photographs in the field and transferred to a 1:24,000 topographic base (Plate 1) using a PG-2 stereoplotter. Elevations and positions of contacts, faults and other geologic features were located within about ± 30 ft (10 m).

SEDIMENTARY ROCKS

An 8,000-ft (2.5 km) thick section of Permian through Cretaceous sedimentary rocks is exposed in the Copper Creek Benches quadrangle (Plates 1, 2). Drilling in Garfield County has penetrated Cambrian rocks (Doelling, 1975, p. 12), indicating that at least 16,000 ft (4900 m) of sedimentary deposits underlie the map area. The Permian, Triassic and Jurassic rocks are a varied assemblage of dominantly continental deposits (Stokes, 1980). During Late Cretaceous time, four transgressive-regressive cycles occurred as the Western Interior seaway advanced and retreated across the region (Peterson et al., 1980). Detailed descriptions of stratigraphic units and ancient sedimentary environments within the Henry Mountains are given by Hunt (1953, p. 36-86), Doelling (1975, p. 21-48), Peterson (1980), Stokes (1980), Smith (1984), and Peterson (1988). Here, we briefly describe the lithologic characteristics of formations mapped within the study area.

Permian System

Cutler Formation. Although Lower Permian rocks of the Cutler Formation are exposed only at the upper elevations of the Mount Hillers and Mount Ellsworth domes (Fig. 1, Plates 1, 2), they probably underlie the entire map area. About 18 miles (30 km) to the west, nearly flat-lying members of the Cutler Formation, including the Cedar Mesa Sandstone Member, Organ Rock

Tongue, and White Rim Sandstone Member, crop out adjacent to Lake Powell. Arching of sedimentary host rocks over the central porphyritic diorite intrusions forming the domes uplifted the Cutler Formation at least 1.4 miles (2.3 km) over Mount Hillers and 1.1 miles (1.8 km) at Mount Ellsworth. These Lower Permian rocks are in contact with Tertiary diorite porphyry of the central intrusions at Mount Hillers and Mount Ellsworth (Plate 2); there, they are strongly fractured and show significant contact metamorphism.

Cedar Mesa Sandstone Member. The Cedar Mesa is exposed only on the southern flank of Mount Hillers, above about 8200 ft (2500 m) elevation, where it has been metamorphosed to quartzite and is strongly fractured. Regionally, however, the Cedar Mesa is a fine- to medium-grained sandstone composed of mostly subangular quartz with calcareous to siliceous cementation (Doelling, 1975, p. 24-25). It is strongly crossbedded with sets averaging 10 to 30 ft (3-10 m) thick. Locally, a thin bed of sandstone, siltstone, or limestone crops out between the crossbeds. The Cedar Mesa ranges from 700 to 1500 ft (215-460 m) in thickness regionally, and it appears to be eolian in origin, with some waterlain deposits (Doelling, 1975, p. 24-25). Only the upper part is exposed at Mount Hillers.

Thin sections of the metamorphosed sandstone from Mount Hillers display highly sutured quartz grains and a wide range of grain sizes. Warped calcite twins are common within the calcareous cement. Metamorphic textures suggest that the quartz grains recrystallized at high temperatures, but then cooled too quickly to reach equilibrium configurations.

Organ Rock Tongue. At Mount Hillers, the Organ Rock shale is strongly fractured and metamorphosed to green hornfels. It crops out within the upper hinge of the domal flexure (Plate 2) and also near its summit. It is the oldest unit exposed at Mount Ellsworth, and there it is less metamorphosed than at

Mount Hillers. Regionally, the Organ Rock is a reddish brown, fine-grained, silty sandstone with interbeds of reddish sandstone or sandy shale (Doelling, 1975, p. 25). Thicknesses of the Organ Rock are quite varied, ranging from 0-450 ft (0-137 m) regionally; the formation is about 246 ft (75 m) thick on the south flank of Mount Hillers. The Organ Rock Tongue, correlative with the Hermit Shale in the Grand Canyon section to the west, was deposited in continental lowland environments by fluvial and, locally, eolian processes.

White Rim Sandstone Member. The White Rim is a strongly crossbedded, eolian sandstone that is very similiar to the Cedar Mesa Member. On the southern flank of Mount Hillers, it crops out within the steeply dipping central limb of the host rock flexure and over the roof of the central intrusion (Fig. 4). At Mount Ellsworth, exposures of the White Rim extend from steeply-dipping outcrops within the central limb of the host rock flexure to nearly flat-lying patches over the roof of the central intrusion (Plate 2). At both Mount Hillers and Mount Ellsworth, the sandstone is strongly fractured and slightly metamorphosed.

The White Rim is composed of a mosaic of fine- to medium-grained quartz grains, with predominantly siliceous cement. Thin sections from the contact metamorphic zone at Mount Hillers show quartz grains with ragged grain boundaries, epitaxial overgrowths and undulatory extinction. Many quartz grains mutually interpenetrate and rare feldspar grains are crushed. The White Rim is white, yellow or light grey on fresh surfaces and weathers to shades of tan. It ranges from about 195 to 280 ft (60-85 m) thick on the flanks of the domes.

Triassic System

Moenkopi Formation. Composed of interbedded sandstone, siltstone and mudstone, the Moenkopi Formation crops out within the upper portions of the central limb and over the roofs of the Mount Hillers and Mount Ellsworth domes (Plate 2). It unconformably overlies the White Rim Member of the Cutler Formation. The Moenkopi is predominantly chocolate- to reddish-brown in color with beds that range from about one inch (2.5 cm) to several feet (1-2 m) thick. Ripple marks are well preserved within shaly sandstone beds. Where exposed over the domes, the Moenkopi is between 180 and 280 ft (55-85 m) thick. The Moenkopi Formation was deposited under shallow marine conditions, on tidal flats, and on flood plains during a series of trangressive and regressive cycles that occurred in the Early and Middle (?) Triassic (Stewart et al., 1972).

Chinle Formation. Where exposed on the flanks of Mount Hillers and Mount Ellsworth, the Chinle Formation is a lithologically variable unit about 350 to 400 ft (105-120 m) thick consisting of the Shinarump, Monitor Butte, Moss Back and Petrified Forest Members, in ascending order. These are not mapped separately in the Copper Creek Benches quadrangle. The Shinarump Member is composed of medium- to thick-bedded, cross-stratified, yellowish-grey, fluvial sandstone that contains minor lenses of silty mudstone and pebble conglomerate. It lies unconformably on, and fills channels scoured into the Moenkopi Formation. Thicknesses range from 10 to 50 ft (3-15 m) on the flanks of the domes. The Monitor Butte Member, a variegated to predominantly greenish-grey, micaceous, bentonitic mudstone unit, forms slopes over the thin ledges of the Shinarump Member. The Monitor Butte was deposited in fluvial, deltaic and lacustrine environments, and is less than 100 ft (30 m) thick on the flanks of Mount Hillers and Mount Ellsworth. The Moss Back Member is a yellowish-grey to pale-orange, coarse-grained, fluvial sandstone unit. Lenses of chert and limestone pebble conglomerate locally contain silicified wood. Mudstone partings are present in thicker units. Thicknesses range from about 20 to 30 ft (6-9 m) in the map area. The Petrified Forest Member is a slope forming, bentonitic claystone unit with minor interbeds of siltstone and conglomerate. Red, purple, green, lavender, and yellow colors are some of its most distinguishing characteristics. It is formed of fluvial and lacustrine deposits and ranges in thickness from about 230 to 300 ft (70-90 m) on the flanks of Mount Hillers and Mount Ellsworth.

Jurassic System

The Jurassic System in the map area includes the Wingate Sandstone, Kayenta Formation, and Navajo Sandstone of the Glen Canyon Group of Early Jurassic age (Padian, 1989), the Page Sandstone, Carmel Formation, Entrada Sandstone, and Summerville Formation of the San Rafael Group of Middle Jurassic age (Peterson, 1988), and the Morrison Formation of Late Jurassic age (Peterson, 1988)

The Glen Canyon Group represents a 983 to 1370 feet (301 to 416 m) thick sequence of extensive deposits of late Mesozoic terrestrial sediments. The Wingate Sandstone is a reddish-pink to reddish-orange formation that forms prominent cliffs. The Kayenta Formation consists dominantly of reddish-brown, light-gray, and purple sandstone of fluvatile origin. The Navajo Sandstone is grayish-orange, and marked by conspicuous crossbeds of aeolian origin.

Wingate Sandstone. The Wingate Sandstone is a reddish-pink to reddish-orange, fine-grained, calcareous, crossbedded, eolian sandstone formation that forms prominent cliffs. Its lower contact with the Chinle Formation is an uncomformity. The Wingate is exposed within the central limbs of the host rock flexures at Mount Hillers and Mount Ellsworth and ranges from about 200 to 300 ft (61-91 m) thick.

Kayenta Formation. The Kayenta Formation is composed of reddish-orange to reddish-brown, fine- to coarse-grained, crossbedded sandstone, occasionally interbedded with thin, sandy siltstone and minor limestone and mudstone. Beds are lenticular and highly variable in thickness. The Kayenta Formation forms ledges and slopes within the central limb of the Mount Hillers and Mount Ellsworth flexures. It includes fluvial deposits as well as local lacustrine, sabkha and aeolian deposits. Thicknesses range from about 263 ft (80 m) at Mount Ellsworth to 445 ft (135 m) at Mount Hillers.

Navajo and Page Sandstones. The Navajo is a light-grey to light-orange, fine- to medium-grained, eolian sandstone unit, characterized by large-scale cross-stratification. It locally contains thin lenses of lacustrine mudstone and cherty limestone or dolomite. The Navajo Sandstone forms prominent cliffs within the central limbs of the Mount Hillers and Mount Ellsworth flexures. The Middle Jurassic Page Sandstone (Peterson and Pipiringos, 1979), 38 feet (12 m) thick on the SW flank of Mount Ellsworth and approximately 50 feet (15 m) thick on the south side of Mount Hillers, unconformably overlies the massive, crossbedded Navajo Sandstone. It is another crossbedded eolian sandstone unit that was included in the Navajo sandstone for mapping convenience. The total thickness of the Page-Navajo map unit ranges from 520 to 625 ft (160-190 m) in the map area.

In the Henry Mountains, the middle Jurassic San Rafael Group consists of a 825 to 1070 feet (251 to 325 m) thick sequence of the Page Sandstone, the Carmel Formation, the Entrada Sandstone, and the Summerville Formation. The Page Sandstone uncoformably overlies the Navajo, and it consists of reddish orange to reddish-brown crossbedded, cliff-forming sandstone. The Carmel is dominantly red mudstone that includes lenses of light-colored sandstone. It makes a slope-forming bed on the flanks of the domes. The Entrada is formed of reddish-orange earthy siltstone, and it makes prominent slickrock outcrops. The Summerville Formation consists of thin- and even-bedded mudstone and well-laminated red-brown and white sandstone. These rocks were deposited in offshore marine environments, in dune fields and lagoonal conditions marginal to a western sea, and in tidal flat environments.

Carmel Formation. The Carmel is a lithologically heterogeneous unit composed of yellowish-orange to reddish-brown interbedded sandstone, dark-reddish-brown mudstone, grey to greenish-grey limestone and dolomite, and white gypsum. It is quite variable in thickness, 81 to 168 ft (25-50 m) at Mount Ellsworth (Geesaman, 1979), and was deposited in shallow marine, tidal flat, and sabkha environments, and it conformably overlies the Page sandstone. The Carmel crops out as a slope-forming bed within the central limbs of the host rock flexures.

Entrada Sandstone. The Entrada Sandstone forms distinctive reddish-orange to reddish-brown, resistant, rounded ledges that crop out within the steeply-dipping central limb at Mount Hillers and within the lower hinge and peripheral limb of the flexure at Mount Ellsworth. It is a very fine- to fine-grained, quartz sandstone and silty sandstone containing minor siltstone and mudstone beds. Eolian portions often form thick-bedded, massive sections. Thicknesses range from about 560 to 720 ft (170-219 m) from Mount Hillers to Mount Ellsworth.

Summerville Formation. Alternating sandstone, mudstone, siltstone, and shale beds of the Summerville Formation crop out along the long, gently-dipping peripheral limb of the Mount Ellsworth dome. The Summerville is characterized by thin, even beds that are mostly reddish-brown, but sometimes are variegated in shades of red, purple, brown, and green. Its contact with the Entrada Sandstone is a sharp, erosional unconformity; the Curtis Formation, which lies beneath the Summerville nearby, is not present in the map area. The Summerville was deposited in a shallow-water, restricted-marine environment, and it thickness is about 180 ft (55 m) in the map area. For convenience, the Summerville Formation was mapped with the overlying Tidwell Member of the Morrison Formation.

Morrison Formation. The Morrison Formation consists of discontinuous beds of sandstone, conglomerate, mudstone, and claystone. It is subdivided into the three members: the Tidwell Member at the base, which unconformably overlies the Summerville Formation, the Salt Wash Member, and the overlying Brushy Basin Member.

Tidwell Member. In the map area, the Tidwell Member consists mostly of red mudstone with several thin sandstone beds. It was deposited on mudflats and within lacustrine environments, and less commonly as sandstones in fluvial and eolian environments (Peterson, 1988). The Tidwell Member is 76 ft (23 m) thick on the south side of Mount Hillers and 44 ft (13 m) thick at the Shootaring Mine area (Peterson, pers. comm., 1990). Its lower contact is an unconformity with the Summerville Formation, and it is a red slope former like the Summerville, but it has more sandstone and greater variation in bed thickness. For convenience, the Tidwell was mapped with the Summerville Formation.

Salt Wash Member. Light-grey to yellowish-grey and yellowish-brown quartzose sandstone interbedded with conglomeratic sandstone, conglomerate, and green, grey, or purple siltstone and mudstone make up the Salt Wash Member. It is formed of alluvial plain, mudflat, and lacustrine deposits and is locally uranium bearing in the Copper Creek Benches quadrangle. The Salt Wash is a ledgy cliff-former, and it is about 550 ft (170 m) thick in the map area.

Brushy Basin Member. The Brushy Basin Member contains much the same lithologies as the Salt Wash, but the softer, purplish to light green, bentonitic mudstone predominates. Colored chert pebbles are common in conglomeratic lenses. The Brushy Basin weathers to multi-colored, low rounded hills in shades of red, purple, grey, yellow, green, and white. It crops out near the termination of the long peripheral limb of the Mount Hillers flexure. Thicknesses range from about 230 to 450 ft (70-140 m) (Doelling, 1975, p. 43) in the map area.

Cretaceous System

Dakota Sandstone. The Dakota Sandstone rests unconformably on the Morrison Formation and forms thin ledges and slopes within the long, gently-dipping peripheral limb of the Mount Hillers flexure. It is a pale-orange to greyish-yellow, calcareous, locally conglomeratic sandstone that is interbedded with black, carbonaceous mudstone and sub-economic coal beds in its lower portion. Locally, the top of the unit may contain abundant *Pycnodonte* fossils. It was deposited in fluvial, lagoonal-paludal and marginal marine environments. In the southern part of the map area the Dakota Sandstone is locally missing; elsewhere it ranges in thickness up to 90 ft (27 m).

Mancos Shale. In the Henry Mountains area, the upper Cretaceous Mancos Shale conformably overlies the Dakota Sandstone and consists of the Tununk Shale, Ferron Sandstone, Blue Gate Shale, Muley Canyon Sandstone

(Smith, 1984) and Masuk Members. The first three of these crop out in the map area, within the southern and western flanks of Mount Hillers.

Tununk Shale Member. The Tununk is a grey to bluish-grey, bentonitic, offshore marine mudstone and silty shale that forms slopes and badlands topography. Occasional thin beds of very fine-grained quartzose sandstone appear at the base and top of the unit. The Tununk is about 550 to 650 ft (170-200 m) thick in the map area, and its lower contact is conformable on the Dakota Sandstone.

Ferron Sandstone Member. Three lithologically distinct units comprise the Ferron in the map area. The lower unit consists of gray, sandy shale interbedded with thin- to thick-bedded, yellowish-gray to medium-brown, fine- to medium-grained sandstone. Massive, cliff-forming, yellowish-gray or tan crossbedded sandstone forms the middle unit. The upper units locally are coal-bearing, and consist mostly of lenticular beds of sandstone, shale, and carbonaceous shale. The Ferron is conformable on and it interfingers with the Tununk Shale Mmeber. It was deposited in marginal marine, lagoonal paludal, and alluvial plain environments. It is approximately 200 to 285 ft (60-87 m) thick.

Blue Gate Shale Member. The lower part of the Blue Gate is a homogeneous dark grey, calcareous shale that is lithologically similiar to the Tununk Member. It has a sharp, unconformable contact with the Ferron Sandstone Member. The upper part contains yellowish-grey, fine-grained beds of platy, calcareous sandstone interbedded with medium grey, gypsiferous shale. The top of the Blue Gate is eroded in the quadrangle, but near the map area the member is over 1000 ft (305 m) thick in the map area.

QUATERNARY SYSTEM

Alluvium

Pediment Alluvium. Pediments are broad, gently-sloping erosional surfaces of low relief that develop at the base of the Henry Mountain fronts. The pediments in the map area are usually underlain by gently-dipping sedimentary bedrock forming the peripheral limbs of the domal flexures (see Plate 2 (cross sections); Fig. 4). The bedrock is mantled with a thin veneer of alluvium less than 10 feet (3 m) thick that is derived from the igneous domes and is in transit across the pediment surface. The pediment alluvium map unit is divided into older (**Qapo**) and younger (**Qapy**) deposits. Older pediment alluvium is generally 200 feet (60 m) or greater in height above its adjacent modern stream. Soils of older pediment alluvium have Stage III or greater calcic-horizon development, using Gile et al.'s (1966) criteria for distinguishing calcic-soil morphology. Also, the surfaces of older pediment alluvium are more greatly dissected than the surfaces of younger pediment alluvium. Pediments that are undifferentiated with respect to their age are mapped as **Qapu**. The pediment deposits consist mainly of diorite-porphyry clasts with minor amounts of resistant sedimentary rock clasts. Clast size, dominantly in the cobble to boulder range, decreases with distance away from the mountain flanks.

Alluvium. Alluvium includes stream channel, stream terrace, and alluvial fan deposits. An alluvial fan is a low, gently-sloping mass of loose rock that is shaped like an open fan; it is deposited by a stream at the place where the stream issues from a narrow valley or canyon. In the map area, fan deposits (**Qaf**) are present along the flanks of Mount Hillers, and they occur mainly in the pullaway zones of large landslides. The fans range up to 30 feet (10 m) in thickness and they extend for no more than half a mile (1 km) away from the mountain front. The fan deposits are poorly sorted, weakly to strongly bedded, and they are composed of diorite-porphyry clasts with a minor percentage of resistant sedimentary rocks clasts. Clast size, dominantly in the cobble to boulder range, decreases with distance away from the mountain flanks.

Alluvial deposits also form terraces that make a series of step-like ledges along stream valley margins, close to the active stream channel. Higher terraces mark former water levels of the stream. Alluvial terrace deposits (**Qat**) are locally divided into older (**Qato**) and younger (**Qaty**) units based on their surface morphology and height above the parent stream.

In some localities, the morphology of young deposits in stream drainages changes over such short distances that we did not map these deposits separately. The **Qa** map unit locally includes undifferentiated deposits of stream channels and stream terraces. **Qa** may also include deposits that are equivalent in age to alluvial terrace and alluvial fan deposits located upstream or downstream.

Colluvium

Colluvium is a loose, incoherent mass of rock fragments and soil that has been transported a limited distance from its source by surface runoff produced by rain or snowmelt. These deposits mantle the lower parts of the mountains from which they were derived. Within the arched sedimentary rocks on the mountain flanks, colluvial deposits (**Qc**) consist dominantly of sand, silt, and clay derived from underlying sandstone and shale bedrock, and clasts of diorite reworked from pediment gravels. Locally, on the slopes of

Mount Hillers and Mount Ellsworth, colluvial deposits consist predominantly of diorite-porphyry clasts, and these are mapped as **Qcd**.

Alluvium - Colluvium

Alluvial-colluvial deposits (**Qac**) are colluvial materials that have been transported a short distance by running water. These deposits are present on the flanks of Mount Ellsworth, generally on steep slopes below pediment surfaces. There, the alluvial-colluvial deposits have been fed by small gullies from the pediments and they have an alluvial fan form. Older alluvial-colluvial deposits (**Qaco**) are deeply incised, and no longer receive sediment from the pediments. Alluvial-colluvial deposits also fill depressions in landslides on Mount Ellsworth and Mount Hillers.

Mass Movement Deposits

The flanks of Mount Hillers and Mount Ellsworth are locally disrupted by prominent landslides (**Qms**) that range in area up to 5 mi^2 (13 km^2). Pediment deposits and the underlying sedimentary bedrock contained within the landslides are deformed by gravity folds, pullaways, and overthrusting. Some landslides, such as the Gold Creek and Starr Springs landslides, show Holocene activity such as non-integrated, young drainages on their surfaces. Smaller, mainly rotational landslides, less than 1 km^2 in area, are present below escarpments and near streams. These landslides are found within the larger, translational slides, for example, at the southern tip of the large landslide involving old pediment alluvium near Copper Creek at Mount Hillers.

Mapping and field observations suggest that many of the landslides form where a mountain stream traverses a surface of pediment alluvium. The landslide initiates because of increasingly moist climatic changes and/or regional base level lowering. The failure plane usually lies within bentonitic shale beds that dip gently away from the mountain flanks, in the peripheral limbs of the host rock flexures (Plate 2 (cross sections); Fig. 4). Movement of the landslide block creates a pullaway zone in the slope above the slide, and the stream fills this void with alluvial fan or terrace deposits and incises the rocks upstream. This incision undercuts the upper slope of the landslide and results in repeated episodes of slip. These relationships are particularly clear on the east flank of Mount Hillers. In some localities within the map area, the stream has reestablished grade and it has begun to fill in and/or erode the landslide mass and create a new pediment surface. This occurs within the landslide just north of Copper Creek where a young pediment surface (**Qapy**) has deposited young pediment alluvium over an older landslide block containing a strongly disrupted old pediment surface.

Much of the mountainous areas of Mount Hillers and Mount Ellsworth are covered with talus (**Qmtd**), which forms steep rocky slopes with coarse angular fragments of diorite-porphyry, and locally minor amounts of sedimentary rock clasts. The talus collects in chutes between outcrops of diorite porphyry dikes and steeply-dipping sills, and it coalesces into aprons that extend to valley bottoms. Rockfall deposits are included in this unit; they are typically present at the heads and margins of talus chutes. Locally, talus collects in large areas to form talus flows (**Qmtf**). Several talus flows are present on Mount Hillers, although only one is present in the quadrangle, on the northwestern edge of the map. The morphology of the talus flow is much like that of a rock glacier: an active talus slope feeds the lobate-shaped flow, whose surface is composed of bouldery ridges and swales terminated by a steep, downslope face.

Marsh deposits

Deposits of spring fed marshes (**Qsm**) consist of organic-rich, fine-grained sediment deposited in closed depressions, which are typically ponds overgrown with reeds and other vegetation. These ponds reflect internal drainage networks on active or recently active landslides.

Highway Fill

Causeways of Utah State Highway 276 that cross canyons of the west side of Mount Ellsworth consist of fill (**Qfh**) excavated from adjoining roadcuts, most of which lie within landslide deposits.

IGNEOUS ROCKS

Tertiary System

Diorite porphyry, composed of plagioclase, hornblende, magnetite, and scattered quartz phenocrysts in a fine-grained groundmass, forms the central intrusions at Mount Hillers and Mount Ellsworth and the numerous sills and dikes that crop out within these domes. Although the diorite is strongly altered within the central intrusion at Mount Ellsworth, elsewhere it is a fresh, light-grey rock with abundant phenocrysts of white plagioclase and dark hornblende. The total volume of igneous rock was estimated by Jackson and Pollard (1988) to be about 13-14 mi^3 (21-23 km^3) at Mount Ellsworth and 21-30 mi^3 (34-49 km^3) at Mount Hillers, based on geologic cross sections and aeromagnetic modelling of the domes.

STRUCTURAL GEOLOGY

Henry Basin

The Copper Creek Benches quadrangle lies on the southern edge of the Henry basin, a north-south trending, asymmetric structural low that is about 100 mi (170 km) long and 50 mi (85 km) wide. Strata have regional dips of less than 2° throughout most of the basin, the axis of which lies west of the Henry Mountains (Fig. 1). The eastern edge dips gently westward, and the western limb is formed by steeply eastwardly-dipping strata of the Waterpocket monocline, which is considered Laramide (Latest Cretaceous to Early Tertiary) in age.

Peterson (1984) showed that minor tectonic disturbances during Late Jurassic time considerably influenced deposition of strata in alluvial and lacustrine complexes of the Tidwell and Salt Wash Members of the Morrison Formation. In southern Utah and northern Arizona, thick deposits of the Tidwell and Salt Wash Members tend to occur in present-day structurally low areas, such as the Henry Basin, and thin deposits tend to occur in present-day structurally high areas. This suggests that these basins and uplifts were structurally active in the Late Jurassic, when these rocks were deposited. Tectonic forces active during Laramide time apparently rejuvenated these prexisting structures and, in addition, caused large monoclines, such as the Waterpocket Fold, to form. Later, in mid-Tertiary time, the Henry Mountain intrusions were emplaced within the gently-dipping eastern limb of the Henry Basin.

Igneous Domes

The domes of sedimentary strata at Mount Holmes, Mount Ellsworth, and Mount Hillers (Fig. 1) are believed to represent successive stages in the growth of shallow magma chambers. About 1.8 to 1.4 mi (3-4 km) of sedimentary rock, from the Permian Cutler Formation to the Cretaceous (Campanian) Tarantula Mesa Sandstone (Smith, 1984), overlay these intrusions at the time of their emplacement in the mid-Tertiary (Jackson and Pollard, 1988). Our mapping demonstrates that these sedimentary strata, now partially eroded from the domes, were uplifted about 0.75 mi (1.2 km) at Mount Holmes (Fig. 4), 1.1 mi (1.8 km) at Mount Ellsworth and at least 1.4 mi (2.5 km) at Mount Hillers (Plate 2). The radii of the domes are similiar, between 3.1 and 4.4 miles (5-7 km). The strata over the domes have a doubly-hinged shape, composed of a concave-upward lower hinge and a concave-downward upper hinge. A central limb of nearly constant dip joins these hinges; this limb dips 20° at Mount Holmes, 50°-55° at Mount Ellsworth, and 75°-85° at Mount Hillers. Numerous, concordant diorite sills are interleaved with the sedimentary host rocks near the central portions of the domes. The distal portion of each dome is composed of a gently dipping peripheral limb 1.8 to 2.4 mi (3-4 km) long, presumably underlain by sills and minor laccoliths.

Whether the central intrusions under the domes are laccoliths or stocks is the subject of controversy. On the basis of his observations in the Henry Mountains in the late 1880's, Gilbert (1877) concluded that the central intrusions grew from sills by lifting and bending of a largely concordant overburden (Fig. 2). More recently, Hunt (1953) concluded that the central intrusions are cylindrical, pipe-like stocks, surrounded by zones of shattered host rock. He suggested a process in which a narrow stock is injected vertically upward; the stock pushes aside and domes the sedimentary strata as it grows in diameter. After emplacement of the stock, tongue-shaped sills and laccoliths are injected radially from the discordant sides of the stock. Mount Holmes, Mount Ellsworth, and Mount Hillers were taken to represent progressive stages in this process (Fig. 3).

Jackson and Pollard (1988) presented new geologic mapping, part of which is shown in this report, as well as detailed cross sections of the host rock flexures (Fig. 4, Plate 2), models of the shapes and volumes of the central intrusions based on regional aeromagnetic surveys, paleomagnetic data showing the sequence of intrusion at Mount Hillers, and models for some of the mechanical differences that characterize stocks and laccoliths. This work supports a laccolithic origin for the magma chambers underlying the southern three Henry Mountain domes and gives a sequential progression of magmatic and deformational events in their growth.

The first stage in the development of each dome involved the intrusion of numerous horizontal diorite sills, presumably fed by dikes (Fig. 5a). Many of the sills formed a radiating pattern around the domes. Jackson and Pollard (1988) hypothesized that one such sill grew near the base of the Permian Cutler Formation to a sufficient radius to begin thickening by bending the entire 1.8 to 2.4 mi (3-4 km) thickness of overburden. The growth of this laccolith was enhanced by its circular plane shape and by local heating of the host rock by numerous slightly older sills. Even a small divergence from a circular plan shape to an oval one requires a very large resisting bending moment at the end of the shorter axis relative to the longer axis, and this greatly diminishes the ability of the intrusion to lift its host rocks (Pollard and Johnson, 1973). As this central laccolith inflated, the overlying sills were rotated and the host rock flexure passed through an early bending stage of deformation observed at Mount Holmes (Figs. 4, 5b). The overburden developed an effective mechanical thickness of between 1600 ft (500 m) and 6300 ft (1930 m) as layers slipped over one another on bedding-plane faults, which are spaced at about 490-660 ft (150-200 m) intervals within the exposed host rocks at Mount Holmes and Mount Ellsworth. Networks of small faults with normal and reverse components of slip accomodated much of the bending and stretching strains within the strata (Jackson and Pollard, 1990). As the central intrusion grew to a volume of 12 to 20 mi^3 (20-35 km^3), the hinges of the overlying flexure tightened, and the central limb steepened to almost vertical, as observed at Mount Hillers (Plate 2). At the edge of the dome, the cumulative effect of the continued intrusion of satellitic sills and laccoliths was to incline the overburden over the length of the long peripheral limb. During the last stage of the intrusive process, intense fracturing and contact metamorphism of the host rock was limited to a thin zone, perhaps 165 to 325 ft (50-100 m) thick, at the immediate contact with the central intrusions at Mount Hillers and Mount Ellsworth.

ECONOMIC GEOLOGY

Uranium and Vanadium

Fluvial sandstone beds of the Salt Wash Member of the Upper Jurassic Morrison Formation are the principal hosts of uranium and vanadium ore in the southern Henry Mountains region (Dubiel et al., 1988). In addition to minor sub-economic deposits of uranium and vandium scattered through the

Salt Wash Member in the Copper Creek Benches quadrangle, two larger ore bodies are tapped by the Delmonte and Tony M. mines (Plate 1). The Tony M. mine, located in Shitamaring (also Shootaring Canyon), was active from 1978 to 1984. It produced about 450,000 tons (81,000,000 kg) of uranium ore over 19 mi (31 km) of workings. The ore grade was about 0.13% U_3O_8. The Ferron Sandstone Member of the Mancos Shale has a localized, sub-economic occurrence of uranium mineralization south of Mount Hillers, but the ore potential of this formation probably is not great because it does not contain sufficient carbonized material (Doelling, 1975, p. 103). Recent drilling northeast of Mount Ellsworth reveals a subeconomic deposit of uranium in subsurface paleochannels of the Upper Triassic Chinle Formation (Dubiel et al., 1987).

Metals, other than Uranium

The igneous rocks exposed within the Henry Mountains have not been found to host important resources of copper, lead, zinc, silver, or gold. The sparse areas of metallic mineralization in the Henry Mountains, such as the summit area of Mount Ellsworth and the Star Mine, located on Mount Hillers just north of the map area, are related to hydrothermal processes associated with the emplaceemnt of the igneous intrusions. Dubiel et al. (1987) and Dubiel et al. (1988) give descriptions of these mineralized areas.

Coal

The Upper Cretaceous Dakota Sandstone and the Ferron Sandstone and Muley Canyon Members of the Upper Cretaceous Mancos Shale contain coal in the Henry Mountains region; only the Dakota and Ferron are present in the

Copper Creek Benches quadrangle. Doelling (1975, p. 78) reports localized, thin, lenticular, sub-economic horizons of coal within the Dakota Sandstone that are usually associated with groupings of shaly beds. The upper zone of the Ferron Sandstone Member contains a coal bed that reaches a maximum thickness of 5.5 ft (1.7 m) at the Stanton mine, located just west of the mapped area (Doelling, 1975, p. 79-80). This mine supplied gold dredges of the Colorado River with fuel for a few years in the 1890's. The coal is high-volatile C bituminous in rank, and the one analysis for the Ferron coal at the Stanton mine (Doelling, 1975, Table 17c) shows a high sulfur content. Reserves for the Garfield County portion of the Henry Mountains coal field, in seams greater than 4 ft (1.2 m) thick, are estimated at 248.7 million short tons (Doelling, 1975, p.83); the Ferron coal in the Copper Creek Benches quadrangle accounts for only a small fraction of this amount.

Sand and Gravel

The Utah Department of Highways has worked two sand and gravel pits (Pits 09059 and 09060) adjacent to Highway 276. The larger of these pits lie within Quaternary pediment gravels deposited on the northwest flank of Mount Ellsworth (Plate 1).

GEOLOGIC HAZARDS

Mass Movement

Mass movement deposits such as landslides, talus and rockfalls, cover large areas within the summit regions and flanks of Mount Hillers and Mount Ellsworth, and along canyon margins. Landslides constitute the greatest mass-movement hazard, whereas talus and rockfall deposits present hazards only to those who venture into the remote mountainous regions or canyon bottoms. Three landslides are traversed by Utah State Highway 276, a popular route to Lake Powell. The Bureau of Land Management campground at Starr Springs lies within a Holocene landslide that is probably still active (Stout, 1983; Noller and Stout, 1988). Dirt roads along the flanks of Mount Hillers traverse several landslides. The real estate development at Gold Creek lies, in part, on landslide deposits.

Landslides on Mount Hillers and Mount Ellsworth inititate on failure planes occupying bentonitic-shale beds in the Tununk Member of the Mancos Shale, and the Brushy Basin member of the Morrison Formation. Landslides also initiate within the Summerville Formation, although this unit is not bentonitic. Beds within these formations dip between 5° and 45° away from the mountain flanks. The landslides are generally elongate masses with straight head scarps, indicating translational failure. Curved head scarps are present where translational landslides have been modified by secondary rotational failures.

The main geomorphic features of landslides in the quadrangle are a headscarp that is present upslope of a pullaway zone, gravity folds, and springs and ponds. Pullaway zones are filled with fining-upwards sequences of sediments derived from upslope streams. Gravity folds are the result of compressive forces within the landslide mass that produce gentle folds above the failure plane. Springs are caused by both groundwater ponding behind a large gravity fold, at Starr Springs, for example, or by exposing an aquifer in a landslide head wall, at Copper Creek, for example.. The piedmont-facing limbs of the largest of these folds are typically the loci of head scarps of younger, smaller landslides. Secondary effects of landsliding include incision of the headscarp and upstream reaches of streams, and subsequent alluviation of the pullaway zones, causing up to 10 m of gravel fill in these areas.

Repeated episodes of slip within some landslides can cause repetition of rock units within the deposit. For example, in the Starr Springs landslide, located on the southeast flank of Mount Hillers, the Mancos Shale lies at the base of an outcrop. It is overlain by a gravelly bed with calcium-carbonate coated diorite clasts. The carbonate is pedogenic and most likely of Quaternary age. This paleosol is conformably overlain by a landslide-derived block of Mancos Shale and, finally, by gravels with late Quaternary soil at the ground surface.

Piedmont development. In the southern Henry Mountains, the most prominent geomorphic feature to form in Quaternary time is the piedmont surface that slopes gently away from the base of the mountains (Plate 1). The piedmont developed through long-term erosion of the mountains by fluvial and mass movement processes.

Geologic mapping of the pediments and landslides that occur at the base of Mount Hillers suggests several stages in the development of the piedmont in the southern Henry Mountains. Piedmont development initiates when the process of lateral planation by streams emerging from the mountain front (Gilbert, 1877, p. 120-127) cause a pediment surface -- a broad, gently-sloping, erosional surface of low relief that is mantled with a thin veneer of alluvium (see p. 13) -- to form (Fig. 6a). A change in climate and/or base level lowering may cause the stream to begin to incise this pediment surface. Stream incision destabilizes the bedrock underlying the pediment alluvium by exposing a potential landslide failure plane, in shale, for example, or by creating a void or canyon into which a potential landslide can move. A translational landslide with internal deformation may then occur (Fig. 6b), and base level is lowered for the stream. The stream may then incise the landslide headwall and deposit small alluvial fans in the pullaway zone of the landslide and in closed depressions created by internal deformation of the landslide mass (Fig. 6c). When the mountain stream reaches a graded condition, a new pediment surface may form at this lower level (Fig. 6d). This new surface may be locally underlain either by a thin veneer of gravel over bedrock or by a thick alluvial sequence. With time, the pediment may be deformed by a new landslide and the process described above may begin anew. Exposures of pediments, landslides, and stream terrace deposits located near Copper Creek, in the NW quadrant of the quadrangle, and near Gold Creek in the NE quadrant of the quadrangle, give good examples of these processes of erosion, deposition, and mass movement.

Floods

The active floodplain of streams in the mapped area approximately corresponds to the **Qa**, **Qat** and **Qaty** map units. Streams in this area reach highest flows during flash floods fed by thunderstorms. Flood hazard is greatest in the canyon bottoms where the flow of water is confined. Floods can occur in the absence of any local rainfall if the flood waters come from heavy rains in the mountains.

Swelling Ground

Bentonitic clays can expand to several times their dry volume when wetted. These clays contribute to the phenomenon known as swelling ground, which can disturb and damage structures and leave dirt roads impassable.

Much of the accessible portion of the quadrangle is underlain by shales that are rich in bentonitic clays. The aridic soils of this area are also rich in expandable bentonitic clays, such as montmorillonite. When wetted from rain or seeps, these clays cause the ground to swell, resulting in damage to structure foundations and road beds. When wet, dirt roads on bentonitic shale units around the Henry Mountains turn into a slippery morass, making vehicular passage difficult, if not impossible.

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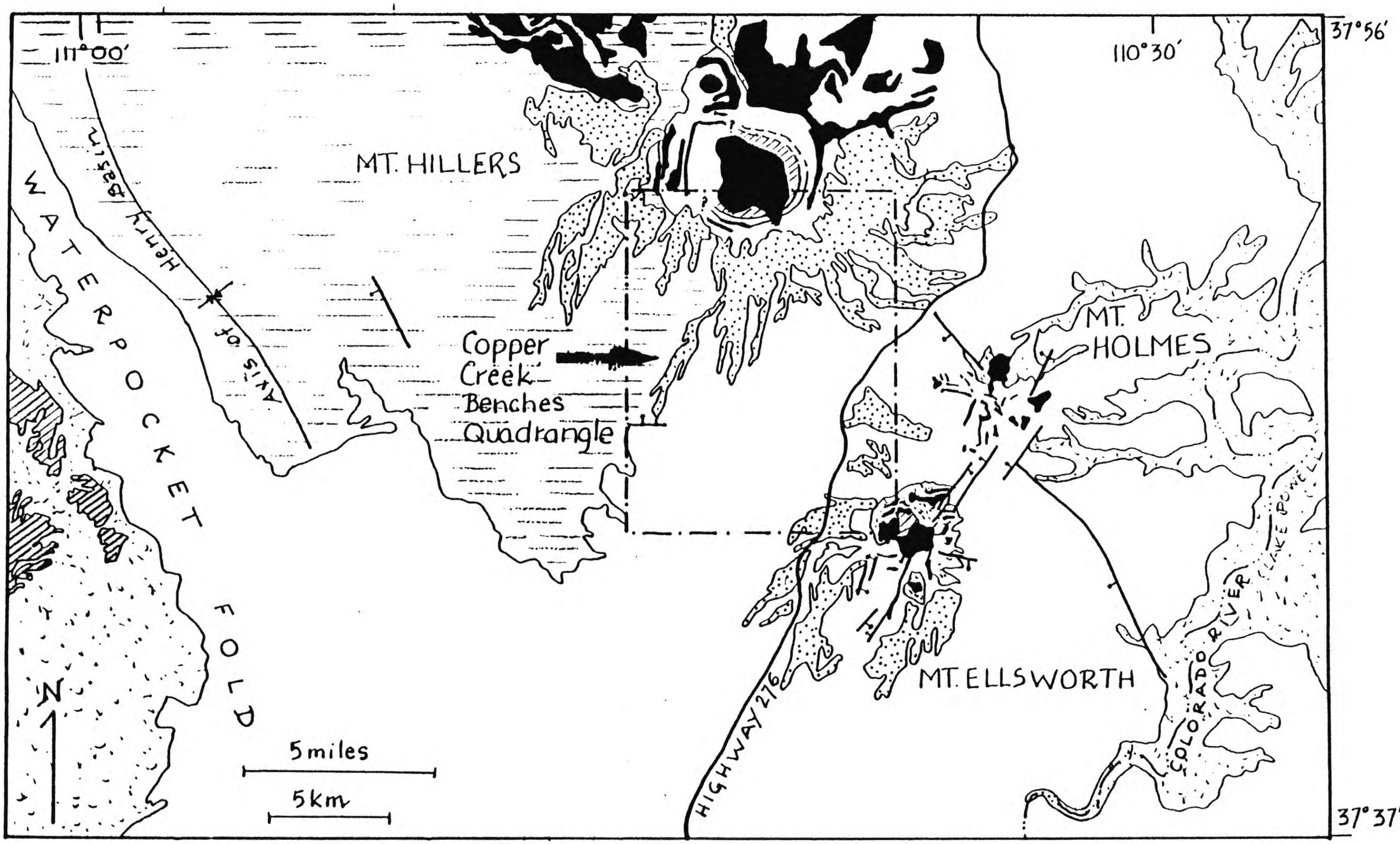


Quaternary deposits

Tertiary diorite porphyry

Cretaceous Mancos shale

Cretaceous Dakota Sandstone, and Jurassic Morrison Formation, and Jurassic San Rafael and Glen Canyon Groups

Triassic Chinle and Moenkopi Formations

Permian Cutler Formation

Fig. 2

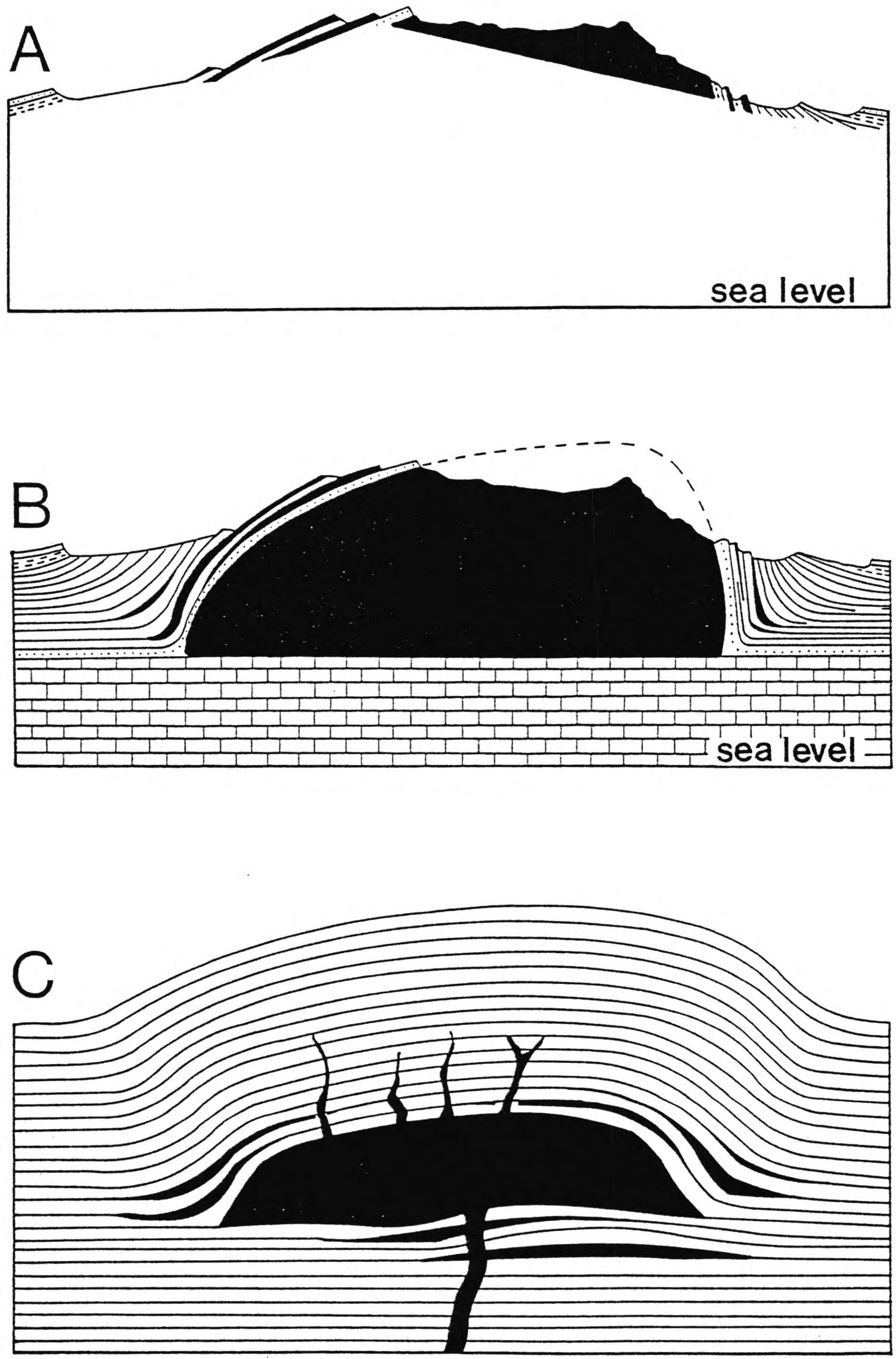
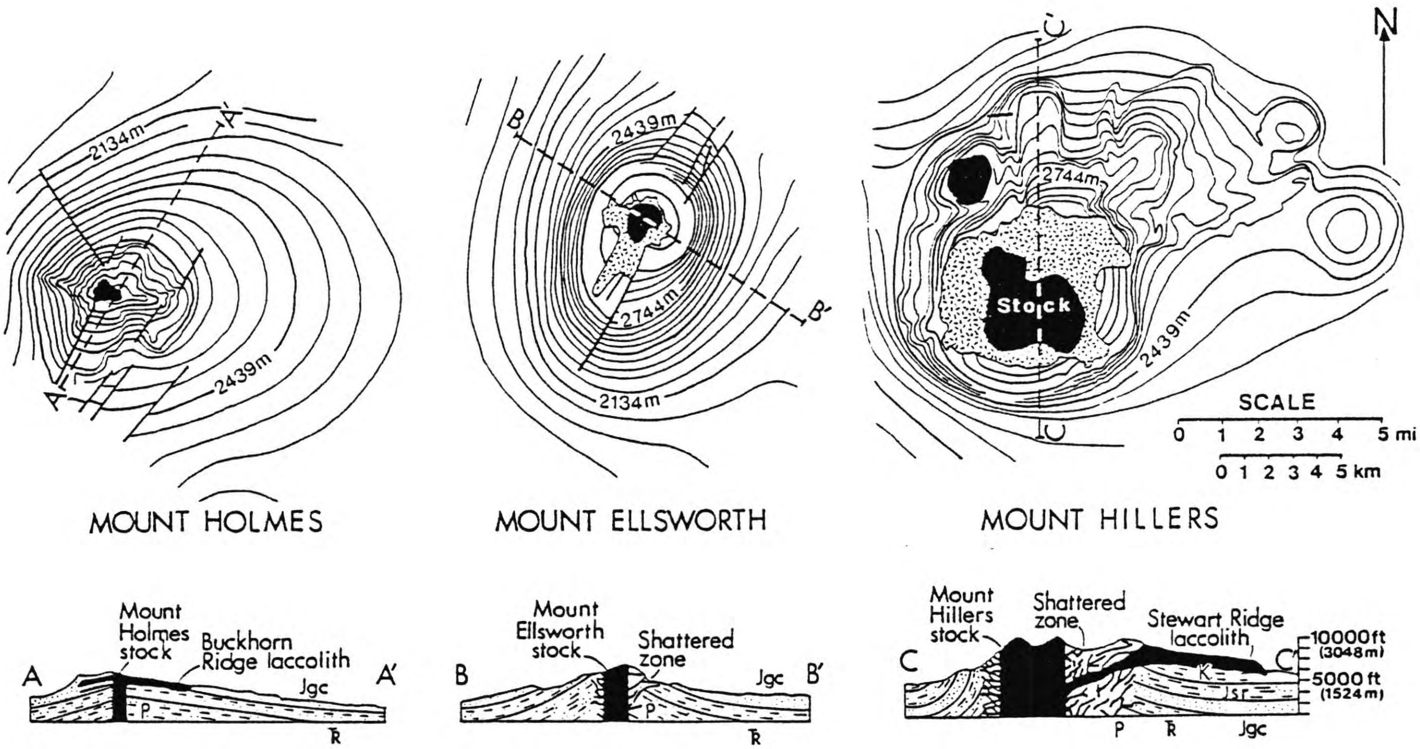
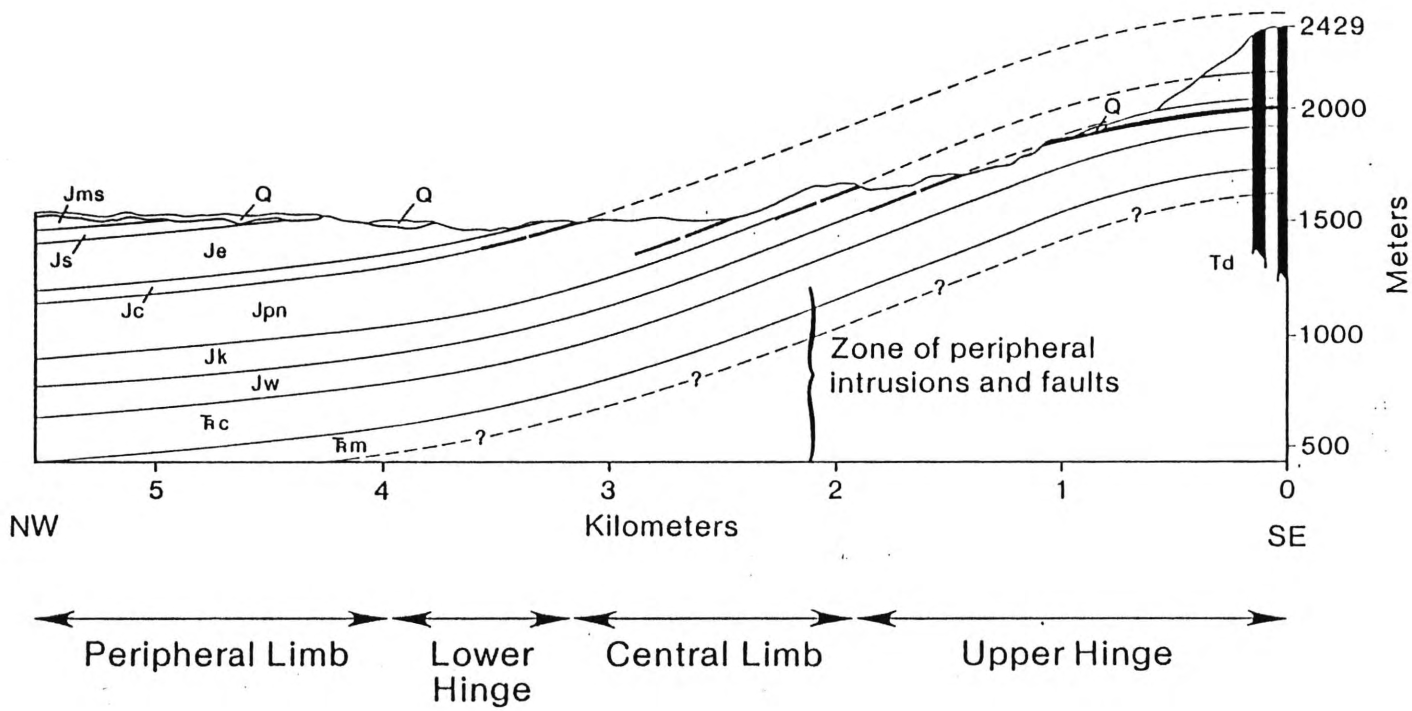


Fig. 3



N
2134m
A'
A
2439m
B
2439m
2744m
B'
2134m
C
2744m
Stock
2439m
C'
SCALE
0 1 2 3 4 5 mi
0 1 2 3 4 5 km
MOUNT HOLMES
MOUNT ELLSWORTH
MOUNT HILLERS
Mount Holmes stock
Buckhorn Ridge laccolith
A
A'
Jgc
P
TR
Mount Ellsworth stock
Shattered zone
B
B'
Jgc
P
TR
Mount Hillers stock
Shattered zone
Stewart Ridge laccolith
C
C'
10000 ft (3048 m)
5000 ft (1524 m)
K
Jsr
P
TR
Jgc


Jms
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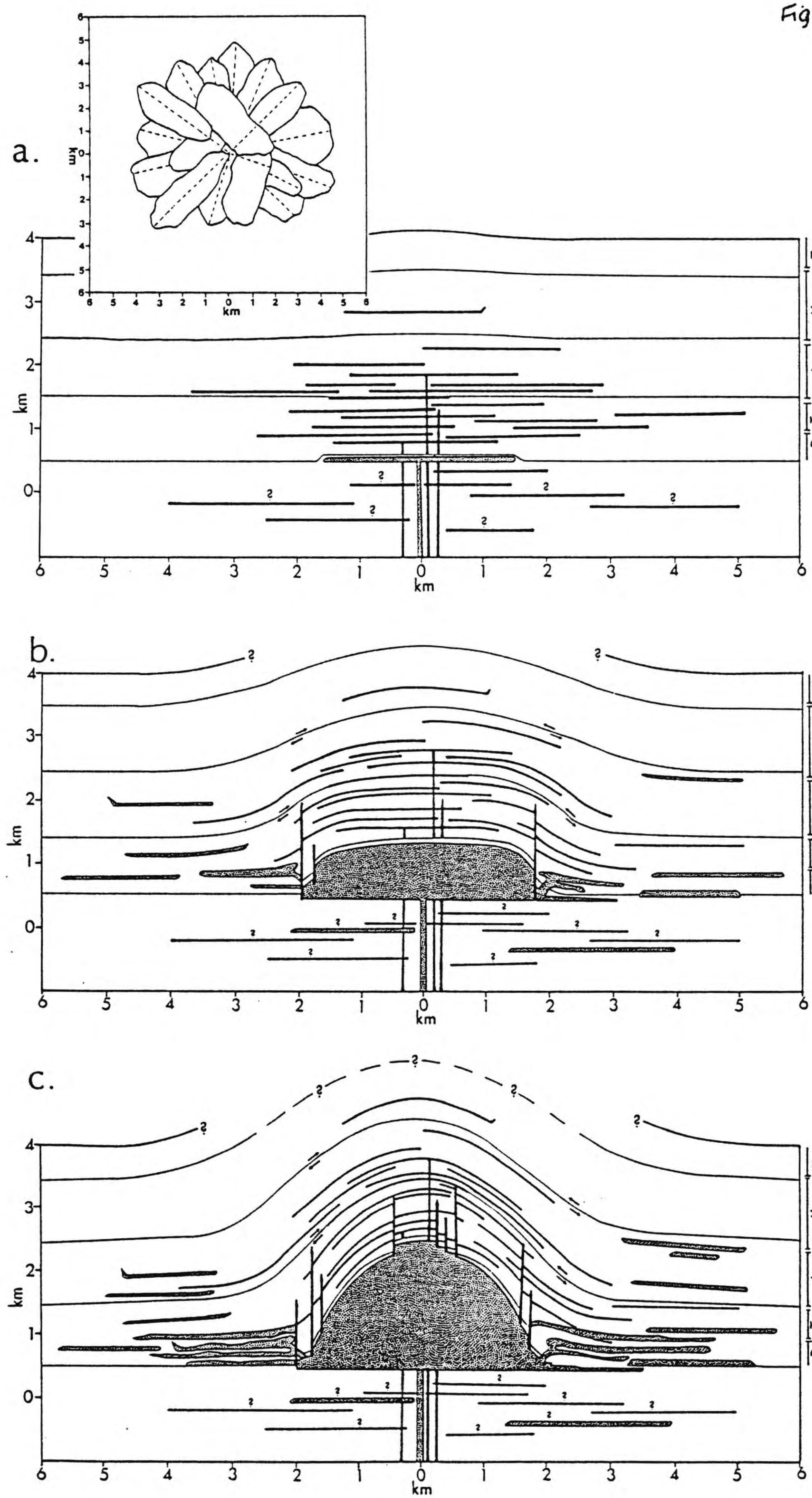
?
Q
Td
Zone of peripheral
intrusions and faults
2429
2000
1500
1000
500
Meters
5
4
3
2
1
0
NW
Kilometers
SE
Peripheral Limb
Lower
Hinge
Central Limb
Upper Hinge

Fig. 4

Fig. 5



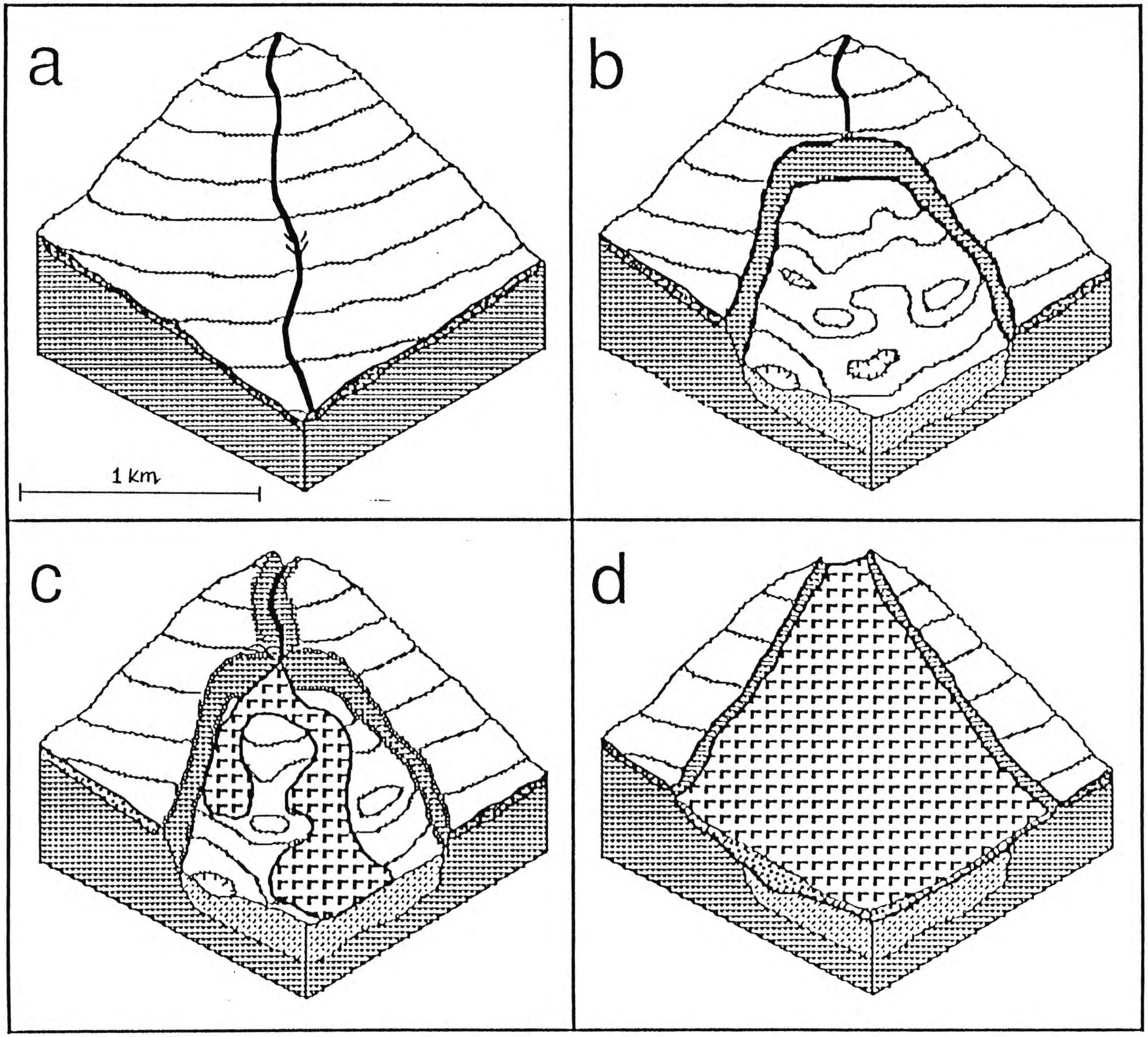


Fig. 6

FIGURE CAPTIONS

Figure 1. Simplified geologic map of the southern Henry Mountains region (after Hackman and Wyant, 1973; Jackson and Pollard, 1988), showing the Copper Creek Benches quadrangle. Sedimentary rocks ranging from upper Cretaceous to Permian in age are uplifted over Mount Hillers and Mount Ellsworth.

Figure 2. G. K. Gilbert's concept of laccoliths in the Henry Mountains (after Gilbert, 1877, and Jackson and Pollard, 1988). (a) Geologic cross section of Mount Hillers, striking N35°W. Diorite is in black. (b) Gilbert's interpretation of the sub-surface structure of Mount Hillers. (c) Idealized laccolithic intrusion with a narrow feeder at its base.

Figure 3. Structure contour maps and cross sections of Mounts Holmes, Ellsworth and Hillers, illlustrating C. B. Hunt's concept of the relationship between the stocks, uplift of the beds, and development of the shattered zones (after Hunt, 1953, and Jackson and Pollard, 1988). Black=igneous rocks. K=Cretaceous rocks. Jsr=San Rafael Group rocks. Jgc=Glen Canyon Group rocks. Tr=Triassic rocks. P=Permian rocks.

Figure 4. Interpretative, radially-oriented cross section through Mount Holmes (after Jackson and Pollard, 1988). See Description of Map Units (Plate 2) for labels of stratigraphic units. Short, dashed heavy lines are bedding-plane faults. Solid heavy black lines are dikes and sills. One mile equals 1.609 km, vertically and horizontally.

Figure 5. Schematic cross sections showing stages in the growth of the central intrusions and domes in the southern Henry Mountains (after Jackson and Pollard, 1988). (a) Emplacement of a stack of tongue-shaped sills and thin laccoliths fed by vertical dikes or pipes. Insert = plan view of early formed intrusions, showing their tongue-like shape. The incipient major laccolith (stipple pattern) has a circular shape in plan view. (b) Thickening of the major laccolith induces bedding-plane faulting, and the overlying sills are tilted. Peripheral dikes and faults form as lateral growth of the laccolith stops. Some sills and thin laccoliths intrude laterally under the peripheral limb of the dome. (c) The major laccolith, now probably formed of multiple intrusions producing a composite body, continues to thicken as the dome grows in height. Beds steepen and stretch on the flanks of the dome, numerous faults lift the roof rock, the zone of peripheral intrusions enlarges, and radial dikes cut upward through the overburden. P, Tr, J, K, T = Permian, Triassic, Jurassic, Cretaceous, and Tertiary sedimentary host rocks.

Figure 6. Fluvial and mass movement processes active in the development of the Henry Mountains piedmont. Solid heavy line = course of mountain stream emerging from mountain front. Solid thin lines = hypothetical topographic contours traversing pediment surface. Light stippled pattern = bedrock underlying pediment alluvium and landslide mass. Heavy stippled pattern = alluvial fan material deposited by renewed stream incision within landslide headwall. a) A process of lateral erosion by a stream emerging from the mountain front causes a pediment surface to form. b) Stream incision of the pediment surface leads to the development of a translational landslide with internal deformation. c) As the stream incises a new channel into the landslide headwall, the landslide pullaway zone and closed depressions within

the landslide are filled with alluvial fan material. d) If the stream reaches grade, it may form a new pediment surface at a lower level than the surface shown in (a). The new pediment surface is underlain either by a thin veneer of gravel over bedrock, or by a thick alluvial fill sequence.

EXPLANATION OF MAP SYMBOLS
COPPER CREEK BENCHES QUADRANGLE

Marie Jackson and Jay Noller

Contact; dashed where approximate, dotted where buried

Strike and dip; dashed where approximate

Fault; dashed where approximate, bar and ball on downthrown side. Bedding-plane faults not shown

Symbols within Landslides

Contact between Qms and other map units; dashed where approximate.

Contact of deformed map unit (symbol in parentheses)

Anticlinal fold axis

Synclinal fold axis

Undifferentiated, closely-spaced anticlinal and synclinal fold axes

Scarp; paired barbs towards downthrown side.

Uranium mine

Subeconomic deposit of titanium and zirconium

Subeconomic deposit of coal

Utah State Highway sand and gravel pit

DESCRIPTIONS OF MAP UNITS
COPPER CREEK BENCHES QUADRANGLE

Marie Jackson and Jay Noller

Qapu	Pediment alluvium
Qapy	Younger pediment alluvium
Qapo	Older pediment alluvium
Qa	Alluvial deposits
Qat	Alluvial terrace deposits
Qaty	Younger alluvial terrace deposits
Qato	Older alluvial terrace deposits
Qaf	Alluvial fan deposits
Qafo	Older alluvial fan deposits
Qc	Colluvial deposits
Qcd	Colluvium of diorite clasts
Qac	Alluvial-colluvial deposits
Qaco	Older alluvial-colluvial deposits
Qms	Landslides; affected geologic map unit in parentheses
Qmtd	Talus of diorite clasts
Qmtf	Talus flows

Qsm Marsh deposits

Qfh Highway Fill

Td Diorite porphyry, light grey porphyry with abundant very light grey oligoclase and black hornblende phenocrysts, minor magnetite, and occasional quartz. Weathers dark brown.

Mancos Shale:

Kmbg Blue Gate Shale Member of Mancos Shale - Upper part, interbedded yellowish-grey, very thin bedded to laminated, very fine grained, calcareous, quartzose sandstone and medium grey, gypsiferous shale. Lower part, dark grey, calcareous shale.

Unconformity

Kmf Ferron Sandstone Member of Mancos Shale - Upper part, lenticular carbonaceous shale; coal; olive-grey, fine-grained, quartzose sandstone. Middle part, grayish-yellow, fine- to medium-grained, quartzose sandstone with minor coaly and carbonaceous horizons. Lower part, very thin-bedded, greyish-orange, calcareous, kaolinitic siltstone, sandstone, and shale; coarsening upward.

Kmt Tununk Shale Member of the Mancos Shale - Medium bluish-grey, thinly laminated to laminated, silty, calcareous, gypsiferous and bentonitic shale; minor thin beds of very fine-grained, quartzose sandstone.

Kd Dakota Sandstone - Pale-orange to greyish-yellow, calcareous, very fine- to medium-grained; includes minor beds of siltstone; ledge forming.

Unconformity

Morrison Formation:

Jmb Brushy Basin Member of the Morrison Formation - Upper part, pale-greenish yellow and purple with minor, thin-bedded, fine-grained sandstone; bentonitic mudstone; claystone. Lower part, moderate-red mudstone and claystone.

Jms Salt Wash Member of the Morrison Formation - Light-grey to yellowish-brown, very fine- to granular-grained sandstone with subordinate reddish and greenish bentonitic mudstone, and interbedded conglomeratic sandstone. Cliff forming.

Unconformity

Js Summerville Formation - Alternating pale reddish-brown to light-brownish-grey, even-bedded siltstone, mudstone and shale. Forms steep slopes and cliffs where more resistant younger rocks are present; otherwise forms slopes and benches. Includes the basal Tidwell Member of the Morrison Formation for mapping convenience. The Tidwell Member is a reddish-brown to light-greenish grey mudstone with lesser amounts of yellowish-brown to light-grey, very fine- to fine-grained sandstone. Forms steep slopes or cliffs.

Unconformity

Je Entrada Sandstone - Reddish-orange to reddish-brown, very fine grained, thin-bedded to massive, calcite-cemented, sandstone and minor siltstone; minor gypsum. Weathers to ledges and cliffs with minor slopes and slickrock outcrops.

Jc Carmel Formation - Yellowish-orange to moderate-reddish-brown, very fine- to fine-grained sandstone and dark reddish-brown mudstone; locally contains grey to greenish-grey limestone and coarsely crystalline white gypsum. Slope former.

Jpn Page and Navajo Sandstone - Light-grey to light-orange, fine- to medium-grained, well-sorted massive sandstone; thickly crossbedded; locally contains minor lenses of mudstone and cherty limestone, or dolomite. Cliff former.

Unconformity

Jk Kayenta Formation - Reddish-orange to reddish-brown, fine- to medium-grained, crossbedded sandstone, and laminated sandy siltstone interbedded with minor limestone, mudstone, and intraformational conglomerate; forms ledges and steep slopes.

Jw Wingate Sandstone - Reddish-pink to reddish-orange, very fine- to fine-grained, crossbedded, cliff-forming sandstone.

Unconformity

TRc Chinle Formation - Contains several members, undivided in map area. Upper part: Variegated, slope-forming mudstone, claystone, sandstone, siltstone, limestine, and intraformational conglomerate. Lower part: Ledge- and slope-forming sandstone, conglomerate, siltstone and mudstone.

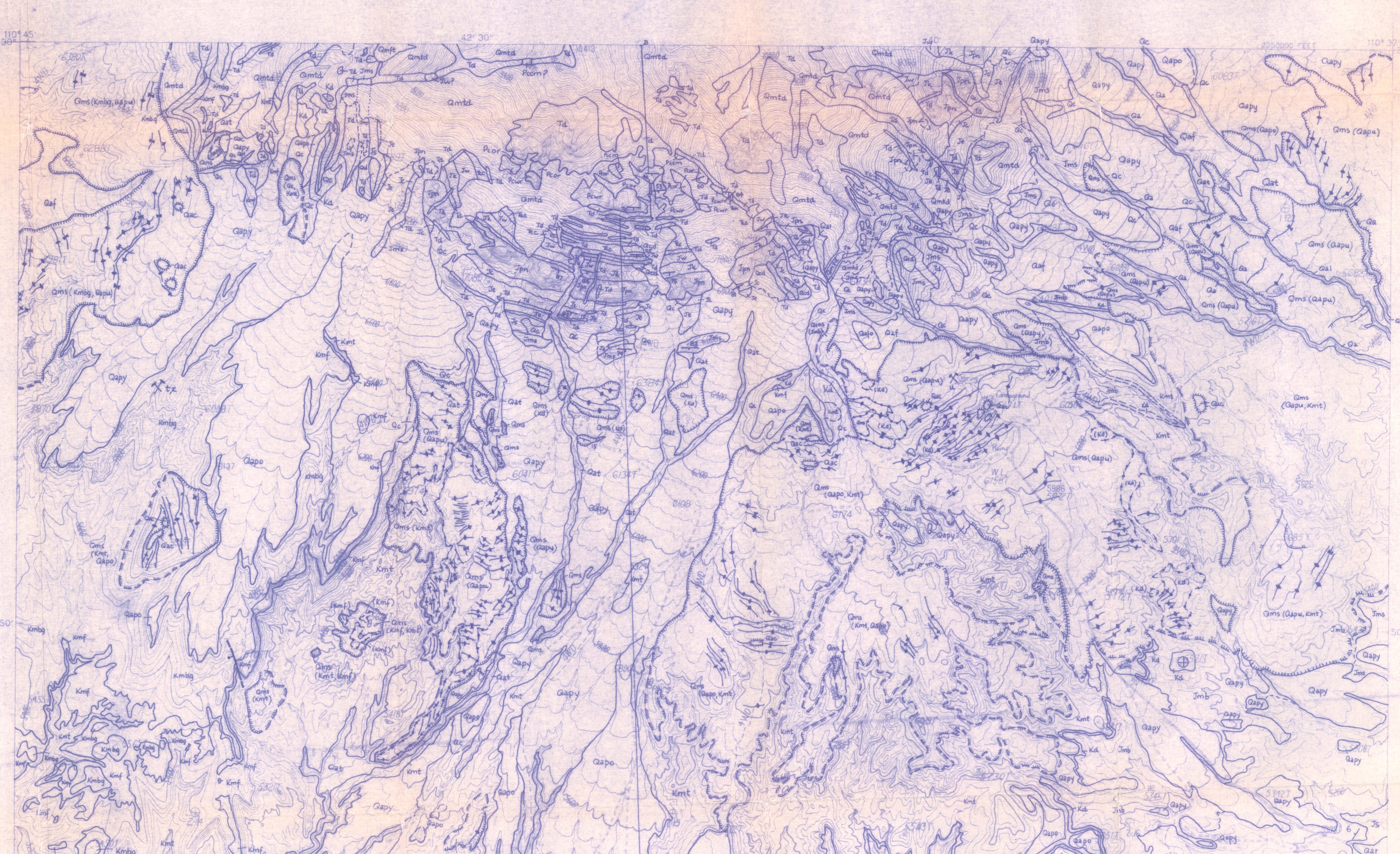
Unconformity

TRm Moenkopi Formation - Pale-red to reddish-brown, interbedded sandstone, siltstone, and mudstone with ripple marks. Forms slopes.

Unconformity

Cutler Formation:

Pcwr	White Rim Sandstone Member of Cutler Formation - Yellow to buff-colored, crossbedded, cliff-forming sandstone.
Pcor	Organ Rock Tongue of Cutler Formation - Reddish-brown, silty, sandstone with scarce sandstone, siltstone and mudstone. Forms slopes.
Pccm	Cedar Mesa Sandstone of Cutler Formation- Light-yellow to light-grey, massive, cliff-forming, cross-bedded sandstone.



GEOLOGIC MAP OF THE COPPER CREEK BENCHES QUADRANGLE

BY

M. JACKSON AND J. NOLLER

February, 1991

TO PLACE ON THE PREDICTED NORTH AMERICAN DATUM 1983 MOVE THE PROJECTION LINES 5 METERS NORTH AND 63 METERS EAST AS SHOWN BY DASHED CORNER TICKS

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PLATE 1

MT HILLERS SW UT 1364-15 040 LAKE POWELL

1: 24000

Plate 2 Stratigraphic Section Copper Creek Benches Quadrangle
Jackson & Nutter

SYSTEM		FORMATION	SYMBOL	THICKNESS FEET (METERS)	LITHOLOGY	DESCRIPTIONS
QUATERNARY		Pediment alluvium, Younger pediment alluvium, Older pediment alluvium, Alluvial deposits, Alluvial terrace deposits, Younger alluvial terrace deposits, Older alluvial terrace deposits, Alluvial fan deposits, Older alluvial fan deposits, Colluvial deposits, Colluvium of diorite clasts, Alluvial-colluvial deposits, Older alluvial-colluvial deposits, Landslides, Talus of diorite clasts, Talus flows, Marsh deposits, Highway Fill	Qapu, Qapy, Qapo, Qa, Qat, Qaty, Qato, Qaf, Qafo, Qc, Qcd, Qac, Qaco, Qms, Qmtd, Qmtf, Qsm, Qfh	0-50 (0-15)		alluvium, colluvium, landslides, talus
TERTIARY		Dioritic Intrusions	Td			porphyritic diorite and quartz diorite light gray
UPPER CRETACEOUS	Mancos Shale	Blue Gate Shale Member	Kmbg	>1000 (305)	coal	marine, shale, minor sandstone, bluish-gray
UPPER CRETACEOUS	Mancos Shale	Ferron Sandstone Member	Kf	200-285 (60-87)		marginal marine, sandstone, shale, yellowish-gray
UPPER CRETACEOUS	Mancos Shale	Tununk Shale Member	Kmt			marine, shale, minor sandstone, dark gray
UPPER CRETACEOUS		Dakota Sandstone	Kd	0-89 (0-27)		marginal marine, sandstone, shale
UPPER JURASSIC	Morrison Formation	Brushy Basin Member	Jmb	230-450 (70-140)		lacustrine, mudstone, variegated colors
UPPER JURASSIC	Morrison Formation	Salt Wash Member	Jms	550 (168)		lacustrine and alluvial plain, sandstone, conglomerate, yellowish-brown
UPPER JURASSIC	Morrison Formation	Tidwell Member (included in Js)				fluvial, lacustrine, mudstone, sandstone red
UPPER JURASSIC		Summerville Fm.	Js	180 (55)		restricted marine, sandstone, mudstone, shale, reddish-brown
MIDDLE JURASSIC		Entrada Sandstone	Je	562-720 (171-219)		eolian, shallow marine, sandstone, reddish-orange
MIDDLE JURASSIC		Carmel Formation	Jc	81-168 (25-51)		shallow marine, sandstone, siltstone, mudstone, reddish-brown
MIDDLE JURASSIC		Page Sandstone				eolian, sandstone, tan
LOWER JURASSIC		Navajo Sandstone	Jpn	520-625 (160-190)		eolian, sandstone, light gray to light orange
LOWER JURASSIC		Kayenta Formation	Jk	263-445 (80-135)		fluvial, sandstone, siltstone, reddish-brown
LOWER JURASSIC / UPPER TRIASSIC		Wingate Sandstone	Jw	200-300 (61-91)		eolian, sandstone, reddish-pink
UPPER TRIASSIC		Chinle Formation	Ŧc	338-390 (106-119)		fluvial, lacustrine, deltaic, mudstone, claystone, siltstone, conglomerate, variegated colors, reddish-brown, yellowish-gray
LOWER AND MIDDLE? TRIASSIC		Moenkopi Formation	Ŧm	180-280 (55-85)		shallow and restricted marine, sandstone, siltstone, mudstone, brown
PERMIAN	Cutler Formation	White Rim Sandstone Member	Pcwr	195-280 (65-85)		eolian, sandstone, light yellow
PERMIAN	Cutler Formation	Organ Rock Tongue	Pcor	246 (75)		marginal marine, sandstone, siltstone, mudstone, reddish-brown
PERMIAN	Cutler Formation	Cedar Mesa Sandstone Member	Pccm	700-1500 (213-456)		eolian, sandstone, ashy yellow

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PLATE 2 209