U.S. Department of Interior

U.S. Geological Survey

Interpretive Geologic Map of Mt. Ajo Quadrangle, Organ Pipe Cactus National Monument, Arizona

by

Janet L. Brown

Open-File Report 92-23

Prepared in cooperation with the U.S. National Park Service

1992

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INTRODUCTION

A geologic excursion through Organ Pipe Cactus National Monument provides an opportunity to study rock types and landscapes suggesting types of mountain-building processes. Figure 1 shows the location of the Monument, which is located 147 mi west of Tucson and 145 mi southwest of Phoenix, Arizona.

The Monument preserves the only population of Organ Pipe cactus (Cereus *thurberi*) in the United States although this species is common in the state of Sonora, Mexico to the south. In 1976, the Monument was designated by the United Nations as an International Biosphere Reserve protecting one of the Earth's major ecosystems, the Sonoran Desert, in southern Arizona and in the state of Sonora, Mexico.

The Mt. Ajo quadrangle includes the popular Ajo Mountain Drive, a one-way loop road which connects hiking trails into Arch Canyon and Estes Canyon to Bull Pasture near the summit of Mt. Ajo. Landforms of the Monument are dominated by steep, blocky mountain ranges and intervening flat desert basins that are characteristic of much of the southern Basin and Range landform province.

Climate

Arid and semi-arid climates characterize the southwest United States and play a major role in the development of landforms as well as the special vegetation that characterizes the Sonoran Desert in the Monument. The Sonoran Desert, named after the state of Sonora, Mexico, ranges in elevation between sea level and 3,000 ft and has the most variable climate of the North American deserts. It is the hottest and farthest south desert in the United States, experiencing large fluctuations in daily temperature combined with rainy seasons in winter and late summer. Landscape or geomorphic processes here are accentuated by the frequent recurrence of climatic events, long periods of sunshine at high sun angle, and wide daily range of temperatures and wind. Additionally, a greater proportion of rainfall is involved in processes of soil-formation and sculpting of the landscape than is lost to evaporation or transpiration by plants.

Landforms of the Monument

Desert landforms of the Basin and Range Province are quite different from the fields of sand dunes that characterize many of the world's deserts. In deserts of the the Basin and Range common landforms include alluvial fans, bajadas, intermittent streams, and desert pavement.

Alluvial fans are broadly convex, fan-shaped, coarse-grained deposits and form in places where stream courses leave the mountain fronts and flow onto the valley plain. Across the fan surfaces radiate entrenched, shallow stream courses following fixed channels. The formation of alluvial fan deposits is partially related to desert climate in which long periods of dryness and accumulation of debris are interspersed with heavy rainstorms resulting in rapid evacuation of material. Basinward, alluvial fans coalesce with each other forming large, slightly undulating low-angle gravel aprons called bajadas that slope smoothly basinward and overlie or are interbedded with the valley fill sediments.

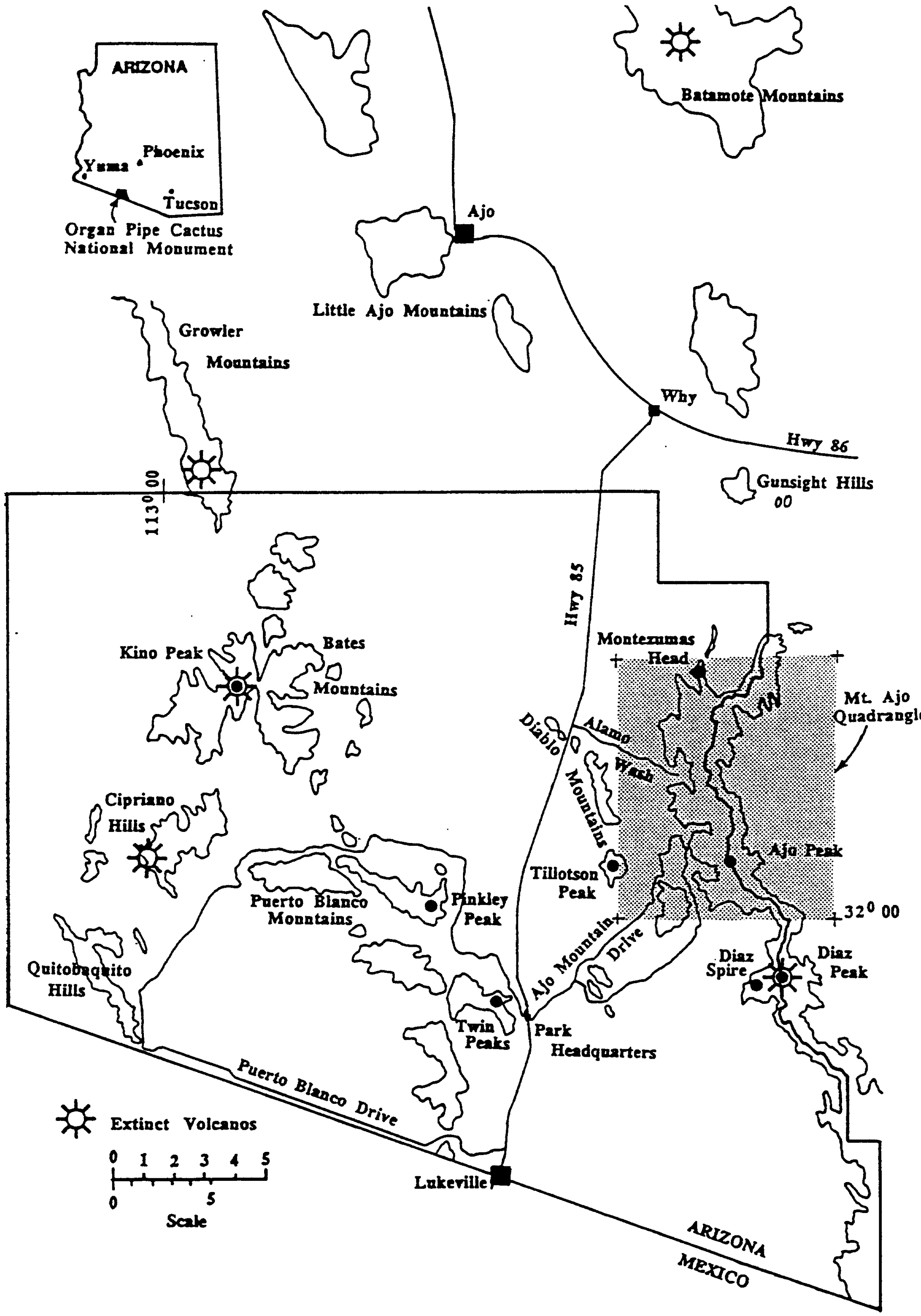
ARIZONA
Phoenix
Yuma
Tucson
Organ Pipe Cactus
National Monument
Batamote Mountains
Ajo
Little Ajo Mountains
Growler
Mountains
Why
Hwy 86
Gunsight Hills
00
113° 00
Hwy 85
Montezumas
Head
Mt. Ajo
Quadrangle
Kino Peak
Bates
Mountains
Diablo
Alamo
Wash
Mountains
Cipriano
Hills
Ajo Peak
Tillotson
Peak
32° 00
Puerto Blanco
Mountains
Pinkley
Peak
Ajo Mountain Drive
Quitobaquito
Hills
Diaz
Spire
Diaz
Peak
Twin
Peaks
Park
Headquarters
Puerto Blanco Drive
Extinct Volcanos
0 1 2 3 4 5
0 5
Scale
Lukeville
ARIZONA
MEXICO

Figure 1

Fine examples of alluvial fans and their associated bajadas are seen north and at the mouth of Alamo Wash on the west side of the Mt. Ajo quadrangle.

Wet and dry desert weather patterns of the desert cause intermittent stream flows. The stream courses are characterized by entrenched walls along stream channels and dominantly coarse-grained materials in the stream bed. The coarse-grained stream sediments display a characteristic braided pattern of interlacing small channels and gravel such as seen along Alamo Wash on the west side of the Mt. Ajo quadrangle. If seen from an airplane, the desert stream courses in intermontane valleys, display branching (dendritic) surface patterns influenced by homogenous flat-lying sediments, cyclic rainfall, and closely spaced mountain blocks.

Examples of desert pavement or stone pavement or desert pavement can be seen along Ajo Mountain Drive southwest of the Diablo Canyon picnic area and are common everywhere in the Monument. Desert pavement consists of armored surfaces composed of angular or rounded fragments, usually one or two stones thick, that cap the underlying fine sandy material. It is particularly common in areas of smooth, gently sloping surfaces between stream channels on the upper part of alluvial fans. Its formation is thought to be related to cycles of freezing and thawing or wetting and drying, that cause coarse fragments to migrate upwards, as well as the action of surface wind and rain that causes the removal of fine material at the surface. Desert pavement surfaces protect the fragile underlying material from further erosion by wind and water.

Geologic Time Scale

The geologic time scale is arranged in chronological order showing the oldest division of time and associated rocks at the bottom and the youngest at the top. The rock units exposed in the Mt. Ajo quadrangle are arranged in a correlation chart showing stratigraphic order from oldest at the bottom to youngest at the top. The timing of the geologic events that have shaped the Earth's surface result from studies of the origins of various kinds of rocks (petrology), coupled with studies of rock layering (stratigraphy) and the evolution of life (paleontology). Studies focussing on the stratigraphy, petrology, and evolution of landforms in the Monument show that the present day geological landscapes are youthful features.

The majority of rocks in the Monument were formed and deposited from eruptions of ancient volcanos. Dates from the analysis of ratios of potassium-argon isotopes in certain of the volcanic rocks indicate that volcanism in the Monument began in Early Miocene time at about 22 m.y. (million years) ago and ceased in Middle Miocene time about 14 m.y. ago (Tosdal and others, 1986). The Gunsight Hills granodiorite (Kgh), of non-volcanic origin, is the oldest exposed rock in the quadrangle. Dates from the analysis of ratios of uranium-lead isotopes in rocks associated with the granodiorite indicated a Late Cretaceous age, or about 70 m.y. old.

Vertical or nearly vertical displacements along breaks in the rock strata are called normal faults and are the mechansim by which the Earth's crust is stretched or extended in the Basin and Range province. In the Monument, two episodes of crustal extension are recorded; an early period lasted from about 36 m.y. ago (Oligocene time) until about 17 m.y. ago. Extensive volcanism took place throughout the Basin and Range province during this extension, and most of the volcanic rocks in the Monument were erupted at this time. A later period of extension began about 10 m.y. ago and ended about 5 m.y. ago.

STRUCTURAL GEOLOGY

The Earth's crust in the Basin and Range province is characterized by east-west stretching, thinning, and flattening. The crust averages about 30 miles thick outside of the Basin and Range province, but within the province, the stretching of the crust has been extraordinary (about 106 miles) resulting in thinning of the crust to about 16 miles.

Because the crust is rigid, it responds to geologic stresses by breaking instead of flowing. Stretching, breaking and pulling apart of the crust in the southern Basin and Range took place along sets of normal faults and commenced about 20 m.y. ago and ended about 5 m.y. ago.

In the Monument, classic graben and horst tectonic structure is shown by the series of aligned mountain ranges and elongate flat desert basins, and characterizes southern Basin and Range geologic structure. An uplifted block bounded by normal faults is termed a horst and most of the mountain ranges in the monument, including Mt. Ajo, are horsts. Mt. Ajo is an assymetric horst because the west side of the block has been lifted higher than the east side. A downdropped block, between horsts, is termed a graben, and these comprise the intervening valleys. The surface break of the fault extends underground along a fault plane that can be either curved or straight. A curved fault plane can contribute an angle of tilt to the exposed strata such as seen on Tillotson Peak when viewed from the Diablo Canyon picnic area. If viewers were flying over the region in an airplane, they would note evenly spaced, northwest to southeast oriented, parallel mountain ranges to the west between the Monument and Yuma, but towards the east and north the spacing and orientation of the ranges is highly irregular. During the later episode of crustal extension in the Monument (10 m.y. ago, Late Miocene), the direction of extension was changed to southwest-northeast. The same extension is related to northwest-southeast orientation of dike swarms in the Mt. Ajo quadrangle. Dikes are composed of volcanic rocks such as rhyolite and basalt that cut across the rock strata and often follow the easiest path along fault planes or fractures of the same orientation as the mountain blocks.

COMMON ROCK TYPES OF MT. AJO QUADRANGLE

Classification of Rocks

Geologists classify rocks into three broad categories by their formative processes: igneous, metamorphic, and sedimentary. Igneous rocks are either solidified in place from deeply-seated molten material (magma) or are deposited at the surface from the eruptions of ancient volcanoes (volcanic). Metamorphic rocks are fundamentally changed from their original composition and appearance by the application of heat and pressure from later episodes of mountain building. Sedimentary rocks are derived and deposited from the erosional debris of other rocks by processes of running water, wind, or moving ice. No metamorphic rocks are found in the Mt. Ajo quadrangle and only a few sedimentary rocks are exposed in the northern part of the quadrangle near Montezumas Head.

Names of rock types are based generally upon appearance, texture, and composition of crystals. Most of the rocks in the Mt. Ajo quadrangle have been deposited by igneous volcanic processes. The composition of the volcanic rocks is essentially some combination of quartz, feldspar, and accessory minerals such as mica or other dark minerals. The rock name is derived from the identification of the ratios of quartz, feldspar, and accessories. Quartz grains often appear in the rock as very hard, clear, shiny, and glassy crystals having irregular boundaries. Feldspar appears as a moderately hard, dull, chalky white or pink, crystal sometimes showing a rectangular shape. Mica flakes are very soft, appear hexagonal or round in shape and commonly are either black (biotite mica) or white (muscovite mica) in color. Other dark minerals, which are often as hard as the quartz, appear as black flecks, rectangles, or tiny needles.

Some common rock types found in the quadrangle include granodiorite, rhyolite, obsidian, andesite, dacite, latite, and basalt.

Granodiorite, a variety of granite, and is classified as a deep seated intrusive rock because it solidifies by slow cooling from molten rock or magma deep inside the earth. Granodiorite can be found in coarsely crystalline bodies called plutons that contain crystals large enough to be distinguished by the naked eye. The Gunsight Hills granodiorite contains mainly quartz, feldspar, and mica and these are easy to see in a hand specimen.

Extrusive volcanic rocks (rhyolite, obsidian, andesite, basalt) are the most common variety of igneous rock in the Mt. Ajo quadrangle and are also composed mainly of quartz, feldspar, and mica. Extrusive rocks either solidify on the surface as fast cooling, micro-crystalline, tabular lava flows or explode from volcanic vents and form rocks containing large, angular, broken pieces in a finer-grained matrix (breccias). The fast-cooling rocks of lava flows (rhyolite, obsidian, andesite, basalt), have constituent crystals that are either very tiny or invisible (aphanitic) in hand specimen. Sometimes crystals much larger than the matrix are present and give a spotted pattern to the rock (porphyry). In aphanitic rocks, mineral composition and rock name is approximated from the overall color. This method is not precise but is sufficient for general purposes.

Rhyolite is the light-colored extrusive equivalent of granite, containing high amounts of quartz and feldspar, but unlike granite is formed at or near the surface. The high quartz content (10 to 40%) of magmas from which rhyolites crystallize retards crystal growth and causes very slow and blocky movement of the flows or very explosive eruptions. It is characteristically white, gray, or pink and nearly always contains a few larger crystals (phenocrysts) of feldspar or quartz imparting a porphyritic texture. The series of rhyolite flows exposed on Montezumas Head (unit Tmr) and throughout the Mt. Ajo quadrangle are the predominant rock type in the quadrangle.

Obsidian (volcanic glass) flows are found in association with the Montezumas Head rhyolite flows (Tm) along the Estes Canyon trail to Bull Pasture. The obsidian usually forms a chilled glassy crust around rhyolite lava flows, commonly about 32 ft thick over the top and around the lava flow front, with a thinner layer at the base. Obsidian absorbs water from the atmosphere, forming an hydrated layer which thickens with time as the water diffuses into the glass. As hydration procedes, the original black shiny obsidian develops a lacey web-like pattern on the surface along cracks and fractures.

Andesite is an intermediate extrusive volcanic rock that is medium gray, dark gray, green, or red in color and often contains light or dark crystals. The dark gray color indicates a higher content of dark colored or black minerals and less than 10 percent quartz. Andesite weathers to a dark brown or reddish brown. Andesite includes varieties called **dacite** and **latite**; latite contains high amounts of certain types of feldspar as phenocrysts, whereas dacite has almost the same composition as andesite but slightly less feldspar.

Basalt is a basic extrusive volcanic rock that is dark gray to black in color, contains no quartz, and has over 70 percent dark colored or black minerals. Because basalt lacks quartz, the flows are fast moving and very fluid.

STRATIGRAPHY OF MT. AJO QUADRANGLE

The unconsolidated sediments that comprise essentially the alluvial fan, bajada, valley fill, and stream deposits are termed surficial sediments and are Quaternary to latest Tertiary in age. Underlying the surficial sediments, four main stratgraphic units have been described in the Mt. Ajo quadrangle. They are from youngest to oldest: the Batamote Andesite Complex (Tb), the Montezumas Head Rhyolite complex, the Childs Latite (Tc) complex, and the Granodiorite of Gunsight Hills (Kgh).

The upper case letter in the designations for the stratigraphic units (for example, Q, T, and K) refers to the age of the unit. Q stands for Quaternary (about 1.6 million years old), T stands for Tertiary (these rocks in Mt. Ajo are about 24 million years old) and K for Cretaceous (these rocks are greater than 65 million years old in the Mt. Ajo quadrangle).

The lower case letters refer to the stratigraphic name for the unit, for example, m for Montezumas Head, c for Childs Latite, and gh for Gunsight Hills. In the Montezumas Head Rhyolite complex, nine parts are separated out and indicated by the first letter of the dominant type of volcanic rock. For the Quaternary and Tertiary sediments (QTsg), sg stands for surface gravels and Tg stands for Tertiary gravels.

Figure 2 is the rock correlation chart for the Mt. Ajo quadrangle and shows vertical sequence and age relationships of exposed strata arranged from oldest to youngest.

Quaternary and Tertiary surficial deposits (QTsg) and **Terrace gravels (Tg)** comprise the youngest strata in the Monument (Tosdal and others, 1986; Eddy, unpub. data). They represent sedimentary processes that have occured from present time to about two million years ago. Some deposits indicate sedimentation during the ice ages when the climate was cooler and wetter, and streams much more active. Generally, the surficial deposits (QTsg) are found on talus slopes, stream terraces, mountain pediments, alluvial fans, and along stream washes or arroyos. In cross-section, such as seen along Alamo Wash, the deposits are unconsolidated, show little stratification or layering, and are flat-lying. The older sediments (Tg) can generally be distinguished by their position underlying the QTsg and show greater cohesion and cementing (lithification), well-developed lenticular channel-forms and cross-bedding indicative of stream deposition. When individual pebbles are broken open, many are composed of Childs Latite (Tc), a red volcanic rock containing large white crystals (phenocrysts), although some pebbles are composed of rhyolite which do not contain phenocrysts.

The Ajo Volcanic Field

Except for the Granodiorite of the Gunsight Hills, the predominant rocks in the Mt. Ajo quadrangle are volcanic rocks of the Ajo volcanic field. The Ajo Volcanic Field is a stratigraphically coherent assemblage of volcanic rocks and subordinate sedimentary and intrusive rocks which are exposed over some 1930 sq mi around the town of Ajo, Arizona. The volcanic stratigraphy of the Ajo Range was first determined by May and others (1981), and was later extented throughout twelve mountain ranges in the region by Floyd Gray, R.J. Miller, D.W. Peterson, and Thomas Younger (unpub. mapping, 1978-1982). Reconnaissance geologic mapping in Pima County, Arizona, is published by R. M., Tosdal, and others (1986). A detailed geologic map of the northern Ajo Range including Montezumas Head is found in Jones (1974). Additional geologic mapping in Organ Pipe Cactus National Monument was performed by A. C. Eddy (unpub. mapping, 1987).

The units of the Ajo volcanic field are from stratigraphic top to bottom, the Batamote Andesite (Gilluly, 1946), rhyolite of Montezumas Head (Gilluly, 1946), and the Childs Latite. The units are separated from each other by unconformities-surfaces where the units above and below appear not be be parallel or show striking differences in their mode of deposition. Unconformities represent gaps in time where either no rocks were deposited or those that were had been subsequently removed by erosion. It is often difficult to determine the amount of time represented by an unconformable surface. The structural dip or tilt of the volcanic sequences in the Ajos is about 3 to 35 degrees to the east. Basin and Range faulting and tilting provided avenues for rhyolitic and basaltic volcanic emplacements such as dikes, volcanic necks or plugs, and domes. The sources for the basalts are vents and cinder cones in the Cipriano Hills, northern Bates Mountains, and southern Growler Mountains of the Monument.

Mt. Ajo consists mainly of the Montezumas Head Rhyolite (Tm) complex and displays broad bands of light and dark-colored volcanic rocks formed mainly during the eruptions of nearby ancient volcanoes. Diaz Spire (about 4 mi south of Mt. Ajo) and seen from the southern part of the Ajo Mountain Loop Road, is thought to be the central feeder conduit (volcanic neck or plug) of an an ancient volcano --the rest of the volcanic cone having been eroded away.

CORRELATION OF MAP UNITS

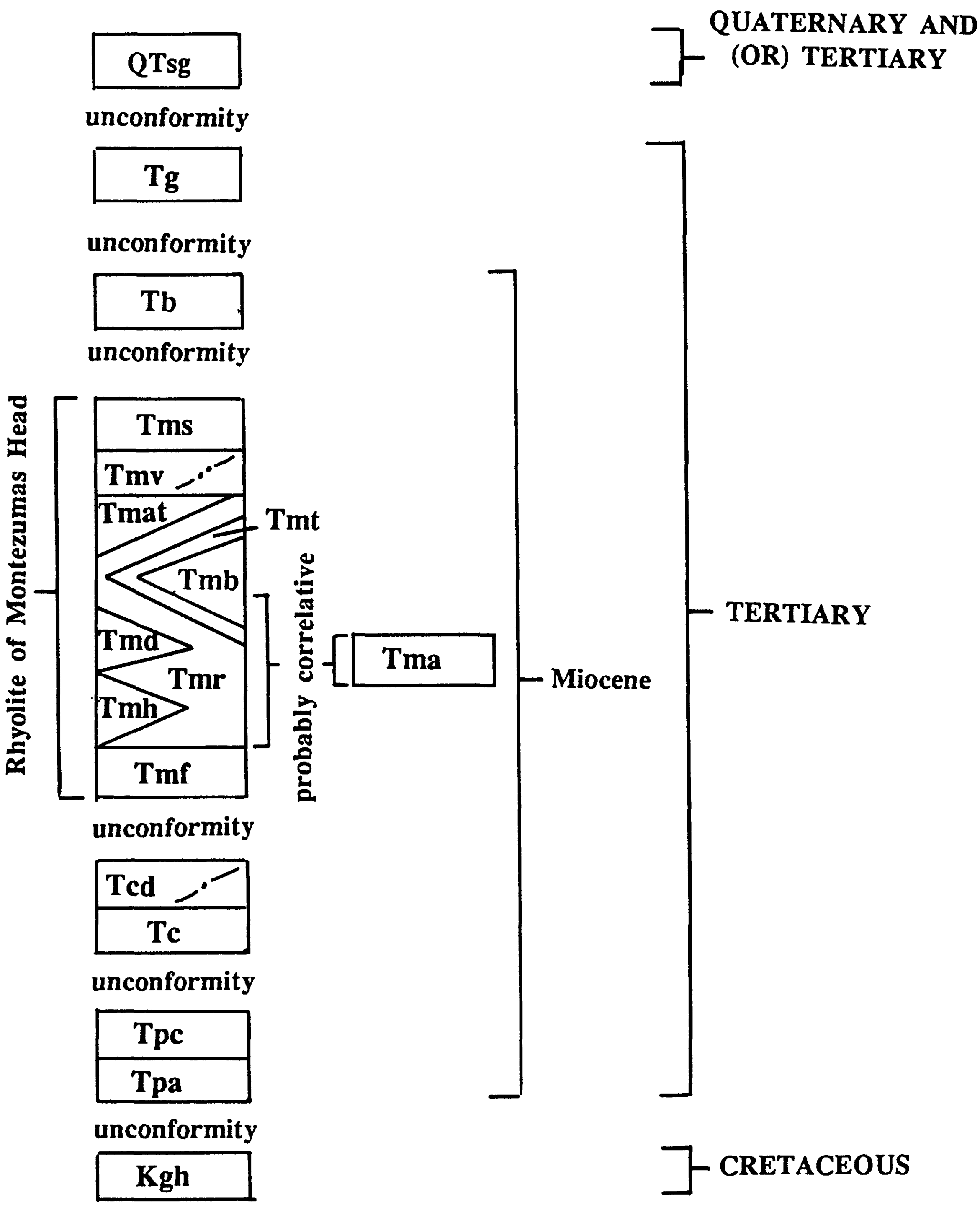

Figure 2

The **Batamote Andesite Complex** undifferentiated (**Tb**) in the Monument is the youngest unit in the Ajo Volcanic Field and is dated at 16-14 m.y. (Gray and others, 1985). The unit has a stratigraphic thickness of 328 ft; individual flows are as much as 49 ft thick. Flows dip gently to the east and unconformably overlie the more steeply dipping older volcanic rocks (Tm and Tc). It exhibits two volcanic facies: extrusive lava flows, and intrusive deposits formed in the throats of volcanos (plugs and necks) or in dikes which are tabular bodies and often follow fault planes cutting across older strata. The extrusive lava flows in the monument correlate with Batamote Andesite of Gilluly (1946), a unit which is named from the Batamote mountains just east of the town of Ajo and north of the monument. The Batamote lava flows dip irregularly away in all directions from a volcanic plug there and suggest that this may have been the throat of an ancient volcano and the source of the Batamote flows.

The **Montezumas Head Rhyolite** underlies the Batamote flow complex and consists mainly of lava flows composed of rhyolite, compacted volcanic ash (tuff), and volcanic mudflows (lahars). The Montezumas Head Rhyolite has been divided into nine units based on rock type in the Mt. Ajo quadrangle. The main unit is Tmr which consists of red-brown rhyolite and forms the massive nearly vertical cliffs with thicknesses ranging from 1454-2208 ft in the main Ajo range. Volcanism ocurred over a period of 1.5 m.y. in Middle Miocene time, from about 17.5 to 16.0 m.y. ago (Tosdal and others, 1986).

The **Childs Latite** (**Tc**) underlies the Montezumas Head Rhyolite and consists of lava flows composed of andesite or flow breccias containing large crystals of feldspar. The Childs Latite was named by Gilluly (1946) from large exposures of flows on the northwest slopes of Childs Mountain north of trhe town of Ajo, north of the Monument. The Childs Latite flows, dated at about 18 m.y. old, appear to originate from an extinct volcano just east of Diaz Peak and southeast of Mt. Ajo in Siovi Shuatak Wash (May and others, 1981). Other minor lava flows, 22-14 m.y. old, are present in the Monument west of the Mt. Ajo quadrangle and their sources are extinct volcanic vents and cinder cones in the Cipriano Hills, Northern Bates Mountains, and southern Growler Mountains.

The **Granodiorite of Gunsight Hills** (**Kgh**) is the oldest unit exposed in the Mt. Ajo quadrangle and is Upper Cretaceous in age (about 74 m.y.)(Tosdal and others, 1986). The exposures are part of the roof of a large intrusive body or pluton about 32 square miles in area. On the west side of the Mt. Ajo quadrangle, north of Alamo Wash Road and east of Highway 85, abandoned mine adits in the unit show copper mineralization in dikes and pure quartz veins intruding the Kgh pluton.

DESCRIPTION OF MAP UNITS

(Adapted from Tosdal and others, 1986)

QTsg ALLUVIUM AND COLLUVIUM (QUATERNARY AND TERTIARY)--Gravel, sand, and minor silt. Quaternary deposits are unconsolidated to weakly consolidated, moderately- to poorly-bedded, cemented by calcium carbonate (caliche), and flat-lying. Clast composition reflects the composition of underlying rock types. Forms alluvial deposits on alluvial fans, intermontane valleys, and on terraces along washes; also forms talus deposits (colluvium) at the bases of cliffs. Includes landform (geomorphic) surfaces of several ages. The older gravels form strongly dissected terraces topographically higher than gravel and sand deposits north of the quadrangle. Unit unconformably overlies the older gravel (Tg) on the east flank of the Ajo Range

Tg TERRACE GRAVEL (TERTIARY)--Boulder conglomerate and sandstone. Tan to brown, pebble to boulder-sized clasts made of volcanic rock. Individual strata are poorly- to well-bedded containing well-developed channels and cross-beds; coarse beds are poorly sorted and contain large angular clasts. Clasts are composed principally of the red porphyritic Childs Latite (Tc), but also include buff and brown rhyolite. Exposed only near southeast end of Kuakatch Pass, on the northeast side of the Ajo Range

AJO VOLCANIC FIELD

The units of the Ajo volcanic field are from stratigraphic top to bottom, the Batamote Andesite (Gilluly, 1946), rhyolite of Montezumas Head (Gilluly, 1946), and the Childs Latite. Each younger volcanic unit unconformably overlies the older.

Tb BATAMOTE ANDESITE (MIOCENE)--Andesite. Medium-gray and less commonly black and red-brown andesite, minor interbedded sandstone and conglomerate, and thin soil horizons. Commonly, the rocks in the lava flows display a smooth, even texture (aphanitic) composed of minute crystals. Occassionally, they show porphyritic texture created by large, light-colored, rectangular crystals (usually feldspar) contained in a medium-gray, very-fine-grained groundmass. The phenocrysts are usually feldspar and weather to a white color. Many of the individual Batamote flows show minute layers of flow banding. The lava flow bases have a red, oxidized basal zone composed of large, angular, tumbled fragments of volcanic rock (breccia) formed by plucking and fragmentation from underlying rocks. Some flows have layers characterized by myriad large gas holes or vesicles (scoria) and they occur at flow margins and on the hummocky flow tops. The scoriaceous layers are formed from pressurized gas bubbles rising and expanding through the viscous molten magma after extrusion. Some flows are composed entirely of blocks of lava formed by exposive eruption, and others are scoriaceous throughout. The individual flows are discontinous and interupted and some include paleosols, indicating a period of quiescence and soil formation between eruptions. This unit is poorly exposed east of Mt. Ajo and on the east side of the quadrangle.

RHYOLITE OF MONTEZUMAS HEAD (MIOCENE)--Rhyolite. Buff, red, brown, and gray. Volcanism occurred over a span of less than 2 m.y. between 17.5 to 16.0 m.y. ago in latest Early Miocene time. The exposed thickness of the unit at Montezumas Head is about 1450 ft and at Mt. Ajo about 2200 ft. In the Mt. Ajo quadrangle, the predominantly rhyolitic rocks of Montezumas Head are divided into nine stratigraphic units depending on rock type (i.e. Tms, Tmat, Tmr, Tmt, Tmb, Tmd, Tmh, Tma, Tmf). Rhyolite dikes cross-cutting the Montezumas Head complex are designated by Tmv.

Tms Sandstone breccia--A complex assemblage of interbedded sedimentary and volcanic rocks comprised of red fluvial conglomerate (Tmf); flows of Childs Latite (Tc) and red rhyolite (Tmr); intruded by dikes of reddish brown rhyolite (Tmv). Only exposed north of Grass Canyon and east of Pitahaya Canyon, and on the northeast side of the Ajo Range.

Tmv Rhyolite Dikes--Gray to black in color, but weathers from reddish-brown to red, and occurs in dikes cross-cutting older units. The rhyolite has a glassy texture and contains phenocrysts of black biotite mica and light-colored feldspar. Along the dike margins are found glassy spherules exhibiting abundant radial cracks. Dikes are usually less than 33 ft wide but locally are as much as 230 ft wide and are consistently oriented north-south and dip steeply to the west. Many dikes were intruded along faults. Dikes are shown by line/ double dot symbol on map (see explanation of symbols).

Tmat Volcanic Ash--Variable composition, but originates as very fine explosive volcanic dust or ash and becomes compacted into a rock called tuff. Brown to orange-brown in color and poorly to densely-welded. Unit is exposed only in the Tillotson Peak area and Diablo Mountains in the Mt. Ajo quadrangle. Some zones of tuff are as much as 230 ft thick and unconformably overly buff colored zones of volcanic ash unit (Tmt) near Tillotson Peak. Forms prominent brown resistant cliffs in Diablo Mountains. Contains angular fragments of basalt and andesite mostly less than 1.5 in., but locally as much as 6 in., in largest dimension.

Tmr Rhyolite--Red, brown, gray, and black rhyolite, occuring in lava flows and volcanic plugs. Weathered surfaces are tan, brown, or maroon, and may be stained black by manganese. Flows locally overlie a white to yellow tuff breccia (Tmt). Unit can locally be traced into a dome. Margins of lava flows sometimes show alteration of glassy constituents towhite minerals called zeolites. Flow banding occurs on all scales and is commonly highly contorted or folded as seen in outcrops of Tmr in Bull Pasture and along the Arch Canyon trail. Sometimes unit has an appearance that looks like tiny marbles (lapilli) compacted together, which is called perlitic texture. Unit forms massive, nearly vertical cliffs, steep slopes, flat benches, and ledges throughout the Ajo Range. Age dates range from 17.1 m.y. to 15.9 m.y. (Middle Miocene) (R. M. Tosdal, unpub. data, 1983).

Tmt Volcanic Ash--Variable composition, but originates as very fine explosive volcanic dust or ash and becomes compacted into a rock called tuff. Buff, yellow-orange, light-yelow, greenish-yellow and white. Contains angular breccia fragments of rhyolite or small spherules (lapilli) or glass shards, and in some places forms a tuffaceous sandstone. Unit thickness is as much as 328 ft and thickness of individual beds varies from less than 2 in. to as much as 16 ft. Member forms either lenses or continuous horizons within the rhyolite flows (Tmr). Locally stratified with well-developed internal stratification and crossbedding indicative of deposition by water; in other places completely contorted or folded by younger or contemporaneous rhyolite flows (Tmr). Locally altered by weathering to white zeolite minerals.

Tmb **Basalt**--Black with sparse, fine-grained, dark green crystals which weather to rust colored patches on the surface. Occurs as a single lava flow, which weathers to red and is as much as 49 ft thick. Near the Diablo Canyon picnic area on Mt. Ajo Drive, it is interbedded with the light-yellow volcanic ash unit Tmt.

Tmd **Dacite**--A variety of andesite. Red-brown, brown, gray, and black porphyritic dacite that occurs as lava flows. Flows are interbedded with rhyolite (Tmr), which is generally the same color but lacks the phenocrysts. Locally includes sparse yellow tuff breccia (Tmt). Exposures tend to be soft and friable, but locally form distinct prominences, such as the reddish-brown ledges and cliffs of the Ajo Range. Flattened fragments of red-brown volcanic rock are incorporated locally.

Tmh **Andesite**--Black, red-brown, gray, purple. Deposited as lava flows, and exposed only on the west slope of the Ajo Range between Alamo Canyon and Estes Canyon, and in Bull Pasture. Unit unconformably overlies Childs Latite (Tc) or is interbedded with rhyolite (Tmr); interbedded relationship suggests that unit is probably the same age as dacite flows of unit Tmd.

Tma **Andesite**--Red-brown, gray, and black occuring in lava flows. The unit underlies white rhyolite tuff breccia unit Tmt. Unit is exposed only on east side of Ajo Range, 2.5 miles southeast of Tonoka and Barajita wells in the Barajita Valley.

Tmf **Sandstone breccia**--Red, yellow or gray. Deposited as poorly stratified, semi-consolidated, red coarse-grained fanglomerate, or as brecciated volcanic mudflows (lahars), or as brown fluvial conglomeratic sandstone. Unit is exposed only north of Montezuma's head and at the mouth of Pitahaya Canyon. It unconformably overlies irregular erosion surface of Childs Latite and underlies rhyolite tuffs (Tmt) and flows (Tmr). The conglomeratic sandstone, 66-656 ft thick, is moderately to poorly cemented (lithified), crudely bedded, and poorly sorted. The conglomerate clasts are pebble- to block-size, subangular to subrounded, and mainly composed of Childs Latite (Tc; red porphyritic rhyolite). Some clasts are composed of gray andesite of pebble- to cobble-size. Matrix is mainly moderately sorted mudstone and sandstone containing some volcanic ash (tuff).

Tc **CHILDS LATITE (MIOCENE)--Latite**. Red; a variety of andesite. Occurs in lava flows and contains very large white feldspar phenocrysts. The overall thickness of the unit varies from 984 to 1969 ft and individual flows range from 16 to 66 ft. Flows in the lower part of the unit weather blue-gray, while those in the upper part weather red-brown to red-gray. Flows contain gas bubbles (vesicular) or are massive. The flows are evenly bedded, and consist of a basal flow breccia 3 to 9 ft thick and an upper scoriaceous flow surface. Flows and domes occur in the Ajo Range, the Gunsight Hills north of the quadrangle, and in the Gu Vo Hills east of the quadrangle. The large feldspar phenocrysts compose 10 to 40 percent of the rock. They are generally about .5 in. long, but can range up to 2 in. along the longest dimension.

Tcd Latite Dikes--Red with white feldspar phenocrysts, occurs in dikes that cross-cut older strata. The dikes are from 6 to 49 ft thick that intrude flows of the Childs Latite. Orientation of dikes are from north-south to north-northwest and dip steeply to the west. Individual dikes are several tens to hundreds of yards long. The mineral composition of the dikes is identical to the Childs Latite flows only slightly less porphyritic. Dikes are shown by line/single dot symbol on map (see explanation of symbols).

RHYOLITE OF PINKLEY PEAK (MIOCENE)--Rhyolite. The rhyolite of Pinkley Peak was described and informally named in the Puerto Blanco Mountains about five miles east of the Mt. Ajo quadrangle. The unit forms the basal part of the Ajo volcanic field and is unconformably overlain by the Childs Latite. This informal name for the volcanic and sedimentary rock sequence stratigraphically below the Childs Latite has been extended to include the rocks in similar stratigraphic position in the Mt. Ajo quadrangle where they are exposed only in an isolated outcrop in the northernmost Ajo Range. Age dates indicate volcanism and sedimentation occurred during the Early Miocene between 22 and 18 m.y. ago (R.M. Tosdal, unpub. data, 1983). Only two of ten stratigraphic units are exposed in the Mt. Ajo quadrangle.

Tpc Sandstone Conglomerate--Pinkish-gray to gray, pebble to cobble conglomerate and fanglomerate, semiconsolidated. Contains lenses of gray sandstone and siltstone, and also lenses of gray andesite, black basalt, and purple tuff. Member is exposed only in the head of Pitahaya Canyon. Clasts are composed of the granodiorite of Gunsight Hills and gray andesite. Unit is well bedded, underlies the Childs Latite (Tc), and is extensively intruded by thin, less than 6 ft wide, dikes of Childs Latite (Tcd).

Tpa Andesite--Maroon, red-brown, and gray.andesite occuring in lava flows containing phenocrysts of feldspar. Magnetite also occurs as black minute octahedral crystals or as black granules. Unit only occurs on east side of quadrangle north of Barajita Valley.

Kgh GRANODIORITE OF GUNSIGHT HILLS (CRETACEOUS)--Light- to medium- gray, medium-grained plutonic rock intruded by dikes composed of varieties of granite. Age dates for the granodiorite indicate a Late Cretaceous age (R.M. Tosdal, unpub. data, 1985). This unit occurs in isolated outcrops north of Alamo Wash on the west flank of the Ajo Range. The granodiorite serves as host rock for copper mineralization indicated by small abandoned mine prospects in the Monument.

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Acknowledgments

This map results from the combined efforts of the U.S. Geological Survey and the U.S. National Park Service. I very much appreciate the financial support provided by the Offices of Energy and Marine and Regional Geology, U.S. Geological Survey. I also appreciate the expertise of Andrea C. Eddy, Richard M. Tosdal, Gordon B. Haxel, Donald W. Peterson, and David A, Sawyer for access to unpublished mapping, helpful suggestions, and critical review. I am very indebted to the time and efforts of John V. Bezy, who facilitated the logistics of this project and offered encouragement and expertise in his specialty of landform evolution. I owe special thanks to Harold J. Smith, Superintendent of Organ Pipe Cactus National Monument for enthusiastic encouragement as well as lodging and material support. I thank Caroline Wilson, Chief Naturalist, and the other fine people I worked with at the Monument.

METRIC CONVERSION FACTORS

Inch-pound unit		Metric equivalent
1 inch (in.)	=	2.54 centimeters (cm)
1 foot (ft)	=	0.305 meter (m)
1 mile (mi)	=	1.609 kilometers (km)

EXPLANATION OF SYMBOLS

CONTACT-dashed where inferred or uncertain

FAULT-Dashed where approximately located; dotted where concealed; bar and ball on downthrown block

DIKES OF RHYOLITE VITROPHYRE OF RHYOLITE OF MONTEZUMAS HEAD (Tmv)

DIKES OF CHILD'S LATITE (Tcd)

15 STRIKE AND DIP OF INCLINED BEDS

25 STRIKE AND DIP OF VOLCANIC FEATURES-includes flow banding, fissile parting, planar alignment of phenocrysts and vesicles