Organ Pipe Cactus National Monument

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Organ Pipe Cactus National Monument

orpi_geology.pdf

Version: 3/29/2019
# Geologic Resources Inventory Map Document for Organ Pipe Cactus National Monument

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**Organ Pipe Cactus National Monument**

- **Map Unit Descriptions**
  - QTal - Alluvium and colluvium (Quaternary and Tertiary)
  - QTIs - Terrace gravels (Quaternary and Tertiary)
  - QTg - Landslide deposits (Quaternary and Tertiary)
  - Batamote Andesite Complex
    - Tbab - Batamore Andesite Complex, vent breccias (late Miocene)
    - Tbai - Batamore Andesite Complex, vent intrusive igneous (late Miocene)
    - Tbb - Batamore Andesite Complex, porphyritic basalt (late Miocene)
    - Tba - Batamore Andesite Complex, basaltic andesite flows and flow breccias (late Miocene)
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  - Childs Latite and coeval plutonic rocks
    - Tcu - Childs Latite and coeval plutonic rocks, undivided (middle Miocene)
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    - Tcl - Childs Latite and coeval plutonic rocks, Childs Latite flows and flow breccias (middle Miocene)
    - Tca - Childs Latite and coeval plutonic rocks, augite andesite (middle Miocene)
    - Tcb - Childs Latite and coeval plutonic rocks, olivine-augite basalt and alkali basalt (middle Miocene)
    - Tcm - Childs Latite and coeval plutonic rocks, monzogranite of Smo Shuatak Wash and related rocks (middle Miocene)
  - Rhyolite of Pinkley Peak
    - Tpb - Rhyolite of Pinkley Peak, olivine-augite basalt dikes (lower Miocene)
    - Tpr - Rhyolite of Pinkley Peak, biotite rhyolite domes, flows, agglomerates, and tuffs (lower Miocene)
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Geologic Resources Inventory Map Document

Organ Pipe Cactus National Monument, Arizona

Document to Accompany Digital Geologic-GIS Data

orpi_geology.pdf
Version: 3/29/2019

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Organ Pipe Cactus National Monument, Arizona (ORPI).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

This document contains the following information:

1) About the NPS Geologic Resources Inventory Program – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.

2) GRI Digital Map and Source Map Citation – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.

3) Map Unit List – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.

4) Map Unit Descriptions – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.

5) Ancillary Source Map Information – Additional source map information presented by source map. For each source map this may include a stratigraphic column, index map, map legend and/or map notes.

6) GRI Digital Data Credits – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:
Stephanie O'Meara  
Geologist/GIS Specialist/Data Manager  
Colorado State University Research Associate, Cooperator to the National Park Service  
Fort Collins, CO 80523  
phone: (970) 491-6655  
e-mail: stephanie.omeara@colostate.edu
About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: https://www.nps.gov/articles/gri-geodatabase-model.htm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage: http://go.nps.gov/gri_products

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park(s), enter "GRI" as a Search Text term, and then select the Search Button.
For more information about the Geologic Resources Inventory Program visit the GRI webpage: https://www.nps.gov/subjects/geology/gri.htm, or contact:

Jason Kenworthy
Inventory Coordinator
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 987-6923
fax: (303) 987-6792
email: Jason_Kenworthy@nps.gov

The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.
GRI Digital Map and Source Map Citation

The GRI digital geologic-GIS map for Organ Pipe Cactus National Monument, Arizona (ORPI):


The GRI used the full extent of the source digital GIS data, and incorporated prominent components of the provided source map (e.g., unit correlation, unit descriptions) into the GRI digital geologic-GIS dataset and product.

Additional information pertaining to each source map is also presented in the GRI Source Map Information (ORPIMAP) table included with the GRI geologic-GIS data.

Index Map

The following index map displays the extent (in dark gray) of the GRI Digital Geologic-GIS Map of Organ Pipe Cactus National Monument and Vicinity, Arizona. The boundary of Organ Pipe Cactus National Monument (as of March, 2019) is outlined in green. The small towns of Ajo and Pisinemo are also shown, as is the boundary (in black) between Arizona and Mexico.

Index map produced by Stephanie O'Meara (Colorado State University).
Map Unit List

The geologic units present in the digital geologic-GIS data produced for Organ Pipe Cactus National Monument, Arizona (ORPI) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., QTal - Alluvium and colluvium). Units are listed from youngest to oldest using the source map’s map unit correlation and unit listing. Information about each geologic unit is also presented in the GRI Geologic Unit Information (ORPIUNIT) table included with the GRI geologic-GIS data.

Cenozoic Era

Quaternary and Tertiary Periods
QTal - Alluvium and colluvium
QTls - Terrace gravels
QTq - Landslide deposits

Tertiary Period
Batamore Andesite Complex
Tbau - Batamore Andesite Complex, flows, flow breccias, and vent intrusive rocks, undivided
Tba - Batamore Andesite Complex, basaltic andesite flows and flow breccias
Tbb - Batamore Andesite Complex, porphyritic basalt
Tba1 - Batamore Andesite Complex, vent intrusive igneous
Tbab - Batamore Andesite Complex, vent breccias
Tsve - Sedimentary and volcanic rocks, undivided

Rhyolite of Montezuma's Head
Tmu - Rhyolite of Montezuma's Head, undivided
Tma - Rhyolite of Montezuma's Head, augite andesite and hypersthene-hornblende andesite of Ajo Range
Tmv - Rhyolite of Montezuma's Head, rhyolite of vitrophyre dikes
Tmat - Rhyolite of Montezuma's Head, crystal-lithic ash-flow tuff
Tmr - Rhyolite of Montezuma's Head, rhyolite, rhyodacite, and minor dacite flows, flow breccias, and plugs
Tmt - Rhyolite of Montezuma's Head, tuff and tuff breccia
Tmb - Rhyolite of Montezuma's Head, porphyritic basalt of Diablo Mountains
Tmd - Rhyolite of Montezuma's Head, dacite of the Ajo Range
Tml - Little Ajo Mountain monzogranite
Tdc - Daniels Conglomerate and associated lake deposits
Tbu - Basalt and basaltic andesite, undivided
Tdu - Dacite, undivided
Tru - Rhyolite flows, dikes, and felsic pyroclastic rocks, undivided
Ttu - Growler Mountain Rhyolite, welded tuff

Childs Latite and coeval plutonic rocks
Tcu - Childs Latite and coeval plutonic rocks, undivided
Tcd - Childs Latite and coeval plutonic rocks, augite latite dikes
Tcl - Childs Latite and coeval plutonic rocks, Childs Latite flows and flow breccias
Tca - Childs Latite and coeval plutonic rocks, augite andesite
Tcb - Childs Latite and coeval plutonic rocks, olivine-augite basalt and alkali basalt
Tcm - Childs Latite and coeval plutonic rocks, monzogranite of Siovi Shuatah Wash and related rocks

Rhyolite of Pinkley Peak
Tpb - Rhyolite of Pinkley Peak, olivine-augite basalt dikes
Tpr - Rhyolite of Pinkley Peak, biotite rhyolite domes, flows, agglomerates, and tuffs
Tprd - Rhyolite of Pinkley Peak, rhyolite, rhyodacite, and dacite flows, flow breccias
Tpt - Rhyolite of Pinkley Peak,olithic lapilli tuff
Tpd - Rhyolite of Pinkley Peak, dacite agglomerate
Tphd - Rhyolite of Pinkley Peak, hornblende dacite flows and agglomerate
Tps - Rhyolite of Pinkley Peak, arkosic and volcaniclastic sandstone
**Cenozoic and Mesozoic Eras**

**Tertiary and Cretaceous Periods**
- **TKgs** - Granite of Senita Basin
- **TKc** - Comelia Quartz Monzonite
- **Gneiss of Chagit Vo**
  - **TKcb** - Gneiss of Chagit Vo, blastomylonitic granodiorite gneiss
  - **TKcq** - Gneiss of Chagit Vo, granodiorite gneiss
  - **TKcm** - Gneiss of Chagit Vo, blastomylonitic monzogranite gneiss
  - **TKcp** - Gneiss of Chagit Vo, protomylonitic granodiorite gneiss

**Mesozoic Era**

**Cretaceous Period**
- **Kgb** - Bandeja Well Granodiorite
- **Kap** - Ajo pluton, granitic rocks and metavolcanic schist, undivided
- **Kgg** - Gunsight Hills Granodiorite and related rocks
- **Kga** - Aguajita Spring Granite
- **Kvu** - Cretaceous volcanic rocks, undivided

**Cretaceous and Jurassic Periods**
- **Kjc** - Conglomerate at Scarface Mountain

**Jurassic Period**
- **Jag** - Rocks of La Abra, greenschist and metaconglomerate
- **Jgr** - Rocks of La Abra, intrusive rhyolite related to Jgr
- **Jgr** - Rocks of La Abra, heterogeneous, altered granitic rocks
- **Jga** - Rocks of La Abra, granite of Agua Dulce Mountains
- **Jgd** - Rocks of La Abra, granodiorite and quartz diorite
- **Japs** - Rocks of La Abra, quartzofeldspathic phyllite and semischist
- **Jap** - Rocks of La Abra, Pozo Nuevo Granite Porphyry
- **Jaq** - Rocks of La Abra, metamorphosed quartz porphyry
- **Jas** - Rocks of La Abra, quartzofeldspathic semischist and phyllite

**Mesozoic and Paleozoic Eras, and Proterozoic Eon**

**Triassic Period, Paleozoic Era and Proterozoic Eon**
- **TRYXo** - Orthogneiss and foliated granite

**Paleozoic Era**

**Mississippian and Devonian Periods**
- **MDm** - Escabrosa and Martin Formations
Cambrian Period
Cs - Bolsa and Abrigo Formations

Proterozoic Eon

Mesoproterozoic Eon
Ycs - Chico Shunie Quartz Monzonite

Paleoproterozoic Eon
Xcq - Cardigan Gniess
Xp - Pinal Schist
Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. All unit descriptions were taken from source map Organ Pipe Cactus National Monument (Geological Reconnaissance). Some unit descriptions include unit symbols (e.g., Tat) that are either a non-mapped subdivision or member of that unit, or is a unit simply not present in the GRI digital geologic-GIS data nor in this document.

QTal - Alluvium and colluvium (Quaternary and Tertiary)

Unconsolidated- to weakly-consolidated and caliche-cemented, poorly-stratified, flat-lying to very shallow-dipping gravel, sand, and minor silt. Moderately- to poorly-bedded deposits include medium- to coarse-grained sand and pebbles, reflecting underlying lithology. QTal is found on talus slopes, dissected terraces or pediments, alluvial fans, in intermontane valleys, and along washes or arroyos. Unconformably overlies coarser-grained, 2- to 6-m-thick deposits (not separately mapped). The unit may include talus gravels and landslide deposits (QTg), areas of terrace gravels (QTls), and scattered outcrops of older bedrock units.

QTls - Terrace gravels (Quaternary and Tertiary)

Massive slump blocks composed primarily of basalt ranging from 200-1500 m wide on the west front of the Growler Mountain range. Unit is unconsolidated, unstratified, and composed of unoriented coarse-grained rubble; locally monolithologic. Slumping due to the instability of poorly consolidated Daniels Conglomerate that underlies lava flows.

QTg - Landslide deposits (Quaternary and Tertiary)

Massive slump blocks composed primarily of basalt ranging from 200-1500 m wide on the west front of the Growler Mountain range. Unit is unconsolidated, unstratified, and composed of unoriented coarse-grained rubble; locally monolithologic. Slumping due to the instability of poorly consolidated Daniels Conglomerate that underlies lava flows.

Batamote Andesite Complex

Tbau - Batamore Andesite Complex, flows, flow breccias, and vent intrusive rocks, undivided (late Miocene)

Gray to black or red-brown (oxidized) basalt, basaltic andesite, and andesite, forming mesa-capping flows, flow breccias, agglomerates, and rare dikes. Isotopic ages bracket the age of the unit between 16 and 14 Ma (Shafiquallah et. al., 1980; Tosdal, unpub. data., 1983). The complex includes minor interbedded lenses of pyroclastic rocks, thin soil horizons, sandstone, and conglomerate. The unit caps the Growler Mountains, Bates Mountains, Ajo Range, Pozo Redondo Mountains, and Gu Vo Hills.

Tba - Batamore Andesite Complex, basaltic andesite flows and flow breccias (late Miocene)

(max ~300 m-thick) Porphyritic, medium-gray to black basaltic andesite with reddish, oxidized flow margins. Individual flows are approximately 2-10 m thick and are usually separated by an oxidized basal flow breccia and a vesicular, glassy upper margin; minor lenses of pyroclastic rocks occur between flows and at the basal contact of the unit; thick soil horizons exist between some flows. Multiple flow sequences are best exposed near Temporal Pass. Other than a slight modal variation in phenocryst content, flows are uniform bottom to top. Unit dips gently (7-14o) to the east. Base of the
unit generally rests upon an irregular surface of the Daniels Conglomerate (Tdc), and locally it rests on monzonite, rhyolite or rhyolite breccia (Tru). Phenocrysts compose about 5 to 15% of the rock and consist of subhedral olivine (0.5-2.5 mm), partially- or completely-altered to iddingsite (prominent in hand specimen), minor euhradal to subhedral plagioclase, twinned clinopyroxene, and rare orthopyroxene. A glomeroporphyritic texture is common. The groundmass is pilotaxitic to intergranular composed of plagioclase feldspar, clinopyroxene, magnetite, and occasional, slightly devitrified brown glass. Basaltic andesite is the youngest bedrock unit in the Growler Mountains and forms minor dikes observed intruding all other units; whole-rock K-Ar ages of 14.4+0.7 Ma (Miller, written comm., 1981) and 15+2.2 Ma (Eberly and Stanley, 1978) have been determined for samples collected at or near the exposed top of this unit.

**Tbb - Batamore Andesite Complex, porphyritic basalt (late Miocene)**

(~100 m-thick) Medium-gray to black porphyritic basalt. Although limited in extent, this unit occupies the same stratigraphic position as the basaltic andesite flows (Tba). Basalt overlies the Daniels Conglomerate (Tdc) and undivided rhyolite (Tru) and crops out only on several plateaus in the southern Growler Mountains near Growler Pass. Composed of 60% or more phenocrysts of subhedral and anhedral iddingsite-rimmed olivine, lath-shaped plagioclase (0.3-1 mm long) showing faint oscillatory zoning, and twinned and zoned clinopyroxene commonly in glomeroporphyritic clusters with plagioclase and altered olivine. Groundmass is interstitial to hyalopilitic, consisting of randomly-oriented plagioclase, granular clinopyroxene, magnetite, brown glass, rare olivine, and secondary calcite.

**Tbai - Batamore Andesite Complex, vent intrusive igneous (late Miocene)**

Dikes and volcanic plugs; dark-colored fine- to medium-grained intergranular to pilotaxitic rock; composed of partly resorbed iddingsite-rimmed olivine phenocrysts (1-2 mm) set in an intergranular matrix consisting of plagioclase, clinopyroxene, magnetite, minor glass, and secondary calcite; olivine phenocrysts are less altered in intrusive rocks than in flow units. Best exposed on the eastern side of the Growler Mountains south of Temporal Pass where it forms prominent steep exposures.

**Tbab - Batamore Andesite Complex, vent breccias (late Miocene)**

(max ~130 m-thick) Reddish-brown to brown, crudely-bedded pyroclastic deposits that consist almost entirely of subrounded to angular scoriaceous ejecta (1 mm - 3 cm); fragments are moderately-sorted; rocks may be locally zeolitized and partially-cemented by caliche; reddish color results from hematitic staining. Dikes of basaltic andesite cut the breccia. Breccias dip steeply away from central vent areas, are crosscut by vent intrusive rocks, and are overlain at the borders of the vents by massive, nearly horizontal flows.

**Tsvu - Sedimentary and volcanic rocks, undivided (Miocene)**

Complex mixture of poorly-stratified, semi-consolidated red conglomerate, breccias, brown, fluvial conglomerate, sandstone, and minor gray and yellow tuff. Locally includes Childs Latite (Tcl) and rhyolite dikes and flows of Montezuma’s Head (Tmd, Tmr) not mapped separately. Conglomerate (20- to 100-m-thick) is composed of moderately- to poorly-indurated, crudely-bedded, poorly-sorted debris flows and fluvial gravel. Conglomeratic clasts (pebble- to boulder-size) are angular to subrounded and are derived from Miocene volcanic rocks: Childs Latite (Tcl) (dominant), basalt, andesite, and rhyolite. The matrix is brown, pebbly, moderately-sorted and generally ranges from tuffaceous mudstone to sandstone. The unit unconformably overlies Childs Latite (Tcl) and underlies or is locally interbedded with Batamote Andesite Complex basalt flows (Tbab) and Rhyolite of Montezuma’s Head tuffs (Tmt) and flows (Tmr).
Rhyolite of Montezuma's Head

Tmu - Rhyolite of Montezuma's Head, undivided (late Miocene)

Thick, stubby rhyolite flows, plugs, and associated tuff and tuff breccia; includes minor dacite and andesite flows, rare ash-flow tuffs, and sedimentary rocks. Volcanism occurred over a period of 1.5 million years in early Miocene time. Flows have yielded K-Ar ages ranging from 17.5-16 Ma (Shafiqullah et al., 1980; Tosdal, unpub. data, 1983). Except for porphyritic basalt (Tmb), volcanic members have common petrographic characteristics: (1) Subhedral to euhedral, moderately- to strongly-embayed, and sieve-textured plagioclase phenocrysts, (2) Augite, biotite (commonly replaced by magnetite), oxyhornblende (commonly opaque-altered), and hypersthene, and (3) a black to gray crystallite-rich groundmass consisting of perlitic glass, fine-grained quartz, feldspar, magnetite, clay minerals, and limonite.

Tma - Rhyolite of Montezuma's Head, augite andesite and hypersthene-hornblende andesite of Ajo Range (late Miocene)

Red-brown, gray, black, or purple augite andesite flows, lahars, tuff breccias, agglomerate, and minor black hypersthene-hornblende andesite flows. Augite andesite may be layered: white rhyolite tuff-breccia succeeded upward by red-brown, partially-oxidized andesite lava, dense, black andesite vitrophyre, and then gray, platy andesite. Augite andesite contains phenocrysts or microphenocrysts (may be megascopically aphyric) of subhedral to fragmental augite and weakly-zoned plagioclase. Groundmass is hyalopilitic, with moderately-oriented plagioclase microlites, sparse clinopyroxene, magnetite, and glass. Hypersthene-hornblende andesite flows are composed of subhedral to euhedral phenocrysts of hypersthene, hornblende, and plagioclase in brown glassy matrix. Unconformably overlies Childs Latite (Tcl) or is interbedded with rhyolite (Tmr). Likely contemporaneous with dacite flows (Tmd).

Tmv - Rhyolite of Montezuma's Head, rhyolite of vitrophyre dikes (late Miocene)

No additional description provided.

Tmat - Rhyolite of Montezuma's Head, crystal-lithic ash-flow tuff (late Miocene)

(70 m thick) Brown to orange, poorly- to densely-welded. Vapor-phase recrystallization and devitrification is variable. Composed of angular basalt and andesite lithic fragments (< 3 cm, locally as much as 15 cm across). Unconformably overlies varying zeolitized tuff (Tmt) near Tillotson Peak, underlies Batamote Andesite (Tba) in Bates Mountains, and forms prominent resistant cliffs in the Diablo Mountains.

Tmr - Rhyolite of Montezuma's Head, rhyolite, rhyodacite, and minor dacite flows, flow breccias, and plugs (late Miocene)

Fresh surfaces are red, purple, brown, gray, or black. Weathered surfaces are tan, brown, or maroon and may be stained with manganese. Rhyolite flows are short and stubby, locally overlie a white to yellow tuff breccia (Tmt) and in places can be traced to domes. Dacite flows are thin and sheet-like. Flow margins are locally zeolitized. Flow banding occurs on all scales and is commonly contorted; more mafic compositions exhibit microscopic fluxion-banding in the groundmass. Flow textures range from aphyric to moderately porphyritic. Phenocrysts are subhedral to euhedral and commonly fragmental. Phenocryst composition includes common plagioclase and biotite, less common augite, diopsidic augite, oxyhornblende, sanidine, and primary bi-pyramidal quartz (plagioclase and quartz comprise ~30% of some rhyodacites and dacites). Biotite is ubiquitous, partially oxidized, and locally
rimmed by augite and quartz. Oxyhornblende is usually altered to magnetite. The groundmass is vitrophyric to hyalopilitic. In glassy rocks, matrix is black or gray perlitic glass-bearing lath-shaped crystallites and tan to brown spherulites. Where strongly recrystallized or felsitic, the groundmass consists of interlocking quartz, alkali feldspar, and magnetite (commonly altered to brown limonite). Limonite-rimmed quartz fills voids where vapor-phase recrystallization is pervasive; calcite fills veins and vesicles in less silicic rocks. Unit may contain unmapped horizons of tuff and tuff breccia (Tmt) and dikes. Forms massive, nearly vertical cliffs, steep slopes, flat benches, and ledges throughout Ajo Range. Flows from this member have K-Ar ages on biotite ranging from 17.1-15.9 Ma (Tosdal, unpub. data, 1983) and 17.4 Ma on whole-rock samples (Shafiqullah et al., 1980).

**Tmt - Rhyolite of Montezuma’s Head, tuff and tuff breccia (late Miocene)**

(max 100-m-thick) Buff, yellow, greenish, and white crystal-vitric and lithic-lapilli tuff, tuff-breccia, agglomerate, and tuffaceous sandstone. Individual beds range from 5 cm to 5 m thick. Forms continuous horizons or lenses within rhyolite flows (Tmr). Massive or stratified with well-developed internal stratification and cross-bedding may be complexly contorted or folded by younger or contemporaneous rhyolite flows (Tmr). Composed of fragmented phenocrysts and angular lithic fragments (Tmr) in a matrix of pumice lapilli and glass shards. Phenocrysts of strongly embayed plagioclase and quartz are common. Feldspar has bleb-like inclusions of diopsidic augite, augite, brown glass, and apatite prisms. Pumice fragments and shards are partly devitrified or variably recrystallized to quartz, alkali feldspar, iron oxides, and ubiquitous brown clay minerals. Diagenetic zeolite alteration is common.

**Tmb - Rhyolite of Montezuma’s Head, porphyritic basalt of Diablo Mountains (late Miocene)**

(max 15-m-thick) Fine-grained, holocrystalline, weakly porphyritic basalt that weathers red. Phenocryst composition includes olivine (generally iddingsitized) and plagioclase (normally-zoned from labradorite to andesine) in a pilotaxitic groundmass of plagioclase microlites, clinopyroxene, olivine, and Fe-Ti oxides. Unit occurs as a single flow intercalated with tuff (Tmt).

**Tmd - Rhyolite of Montezuma’s Head, dacite of the Ajo Range (late Miocene)**

Brown, gray, and black porphyritic dacite flows interbedded with rhyolite (Tmr): locally includes sparse yellow tuff-breccia (Tmt). Phenocrysts of subhedral to euhedral or fragmental plagioclase, augite, and sparse hypersthene, hornblende, and biotite. Mafic phenocryst mineralogy varies between flows. Brown clay minerals are locally pervasive and commonly surround oxidized mafic phenocrysts. Groundmass is composed of flow-banded crystallites. Flattened red-brown pumice may be present. Although generally fissile and friable, exposures locally form distinct prominences, such as the reddish-brown ledges and cliffs in the Ajo Range.

**Tml - Little Ajo Mountain monzogranite (late Miocene)**

Monzodiorite, granodiorite, monzogranite, and quartz monzonite.

**Tdc - Daniels Conglomerate and associated lake deposits (middle to late Miocene)**

(180- to 240-m-thick) Tan, gray, or red, poorly-indurated, shallow-dipping, pebbly to sandy conglomerate, subordinate sandstone and pebbly sandstone. Formally named the Daniels Conglomerate by Gilluly (1946). Clasts are subangular to subrounded (5-20 cm) composed of Cardigan Gneiss (Xcg), Chico Shunie Granite (Yes), Mesozoic granite, and minor hornblende andesite, and Childs Latite (Tcl). Matrix is poorly-sorted, coarse- to medium-grained, friable, and
arkosic. Layering is poorly-defined, but in some areas, pebbly sandstone may show subhorizontal bedding (30-cm-thick). Locally, the unit includes (possible) erosional remnants of lacustrine deposits associated with the Daniels Conglomerate: lacustrine sediments are purplish-pink to tan, fine-grained siltstone and mudstone with gypsum layers as much as 5-cm-thick (exposed thickness <5 m). Lake deposits occur in irregular, discontinuous small basins. Locally the unit may include thin tuffs at the top and welded tuff (Tat) near the bottom. The basal portion of the Daniels Conglomerate interfingers with Childs Latite (Tcl).

**Tbu - Basalt and basaltic andesite, undivided (Miocene)**

In the Growler Mountains, unit is composed of dense, slightly vesicular, medium-gray to dark-gray alkali basalt (unit Tab?). South of the Growler Mountains, unit is not described. In the Pozo Redondo Mountains, unit is composed of dark gray flows and flow breccia containing partially resorbed quartz xenocrysts in an anphatic groundmass (unit Tqb?). Near Cimarron Peak, unit is basalt and basaltic andesite flows, tuffs, and agglomerates comprising the Cimarron Peak Volcano. Lavas are light gray and sparsely porphyritic with 0.5% microphenocrysts of iddinsite-altered olivine. Zeolites and silica are common vesicle fillings.

**Tdu - Dacite, undivided (Miocene)**

In central ORPI, unit is mapped as hornblende dacite. In the Skiport Chuapo Mountains, unit is reddish-brown, dacitic lava flows and densely welded ash-flow-tuff; phenocrysts include biotite and plagioclase and the unit locally contains abundant flattened pumice lapilli.

**Tru - Rhyolite flows, dikes, and felsic pyroclastic rocks, undivided (Miocene)**

In the southern Growler Mountain and the Sikort Chuapo Mountains, unit is composed of rhyolite flows, flow breccias, and dike rocks of variable composition (units Tr and Trg, respectively). In Batamote Mountains, unit is composed of light-gray to tannish-gray, reddish-brown to buff-brown feldspar- and biotite-porphryritic flows and tuffs. Phenocrysts comprise 30-35% of rock and consist of sanidine, quartz, and minor biotite and hornblende. K-Ar biotite dates yielded an age of 19.5 + 0.6 Ma (Gray and Miller, 1984) (unit Trc). East of Pozo Redondo Valley, unit is mapped as two facies: (1) Buff, yellow, or white, crystal-lithic and crystal-lapilli tuff; thickness varies up to 100 m; texture is typically vitroclastic with strongly embayed quartz and plagioclase (unit Ttba), and (2) Phyrctic aphyric flows with phenocrysts of plagioclase, biotite, and, less commonly, clinopyroxene; K-Ar whole rock age of 17.4 + 0.5 Ma (unit Trr). East of the Gunsight Hills, unit is mapped as rhyodacite dikes intruding Cretaceous granodiorite (TKcb).

**Ttu - Growler Mountain Rhyolite, welded tuff (Miocene)**

(30-60 m-thick) Light pink to tan densely-welded tuff. Unit consists of flattened pumice fragments (3-5 cm). Contains crystals of euhedral sanidine and biotite in a glassy matrix. Some vapor-phase minerals occur along the walls of vesicles. Commonly forms 6- to 9-m-thick layers at the base of the Daniels Conglomerate (TdC), resting directly on Childs Latite (Tcl).

**Childs Latite and coeval plutonic rocks**

**Tcu - Childs Latite and coeval plutonic rocks, undivided (middle Miocene)**

Gilluly (1946) originally mapped, described, and named these rocks near Ajo, Arizona. Further mapping has extended the known distribution of the unit to some 12 mountain ranges in the surrounding area (Jones, 1974; Eberly and Stanley, 1978; May et. al., 1981; Gray et. al., 1985, Peterson et al., unpub. mapping, 1979-1982).
Tcd - Childs Latite and coeval plutonic rocks, augite latite dikes (middle Miocene)

No additional description provided.

Tcl - Childs Latite and coeval plutonic rocks, Childs Latite flows and flow breccias (middle Miocene)

(250- to 600-m-thick; individual flows 5-to 10-m-thick) Augite latite flows, flow breccia, flow agglomerate, minor hypabyssal, and more silicic tuffaceous rocks characterized by megacrystic plagioclase phenocrysts. Chemical analyses from throughout the area indicate the rocks are largely of latitic trachyandesite composition, with less abundant shoshonite and andesite (Miller unpub. data, 1984). Fresh surfaces are gray to black, or maroon in iron-oxide stained; weathered surfaces are tan, brown, or purple. Stratigraphically lower flows are thicker, more massive, and less weathered, whereas higher flows are typically thinner and more oxidized. May be interbedded with andesite and basalt (Tca) or Daniels Conglomerate (Tdc). Although flow sequences can vary rapidly in texture and appearance over short vertical and lateral distances, lower flows are typically darker and tend toward blue or gray hues, whereas higher in the section red or brown hues are common. Individual flows are evenly bedded, vesicular to (less commonly) massive and dense, and generally lack internal flow features. Outcrops are typically craggy to blocky. Each flow usually has a basal flow breccia 1-3 m-thick and a scoriaceous, oxidized upper flow surface. Flows have a porphyro-aphanitic to intergranular texture, ranging from holocrystalline to hyalocrystalline. Phenocrysts include plagioclase, euhedral to subhedral augite (less common diopsidic augite) (< 1-mm-long), biotite, oxyhornblende, locally-significant olivine with iddingsite rims, and sparse ilmenite, leucoxene, apatite, and zircon (?). Plagioclase megacrysts are euhedral, complexly oscillatory-zoned and comprise 10-40% of the rock (andesine to oligoclase/sanidine)(0.5- to 4-cm-long) (LeVeque, unpub. data, 1979); margins are commonly embayed; cores contain abundant inclusions of apatite, augite, and devitrified brown glass. Plagioclase size, abundance, and shape account for most variation within and among separate flows. Groundmass is pilotaxitic or intergranular, less commonly cryptocrystalline or glassy. Matrix is composed of plagioclase microlites, clinopyroxene, rare orthopyroxene, disseminated magnetite, minor glass, quartz, and olivine. May contain xenoliths of volcanic or granitic origin. K-Ar isotopic dates from rocks above and below the unit indicate that the Childs Latite was deposited over a very short time in the Early Miocene (~18 Ma) (Tosdal and Miller, unpub. data, 1983).

Tca - Childs Latite and coeval plutonic rocks, augite andesite (middle Miocene)

(max 80-m-thick) Augite andesite flows and flow breccia interbedded with Childs Latite (Tcl). Laterally discontinuous, individually 5- to 15-m-thick. Lighter colored and notably less porphyritic than surrounding Childs Latite flows. Fresh surfaces are generally weathered gray to mottled tan, brown, gray, and maroon. Flows are generally massive and display local weak flow-banding, vesiculated tops, and brecciated bases, with minor autobrecciated and scoriaceous flows. Flow sequences typically rest on a thin (<2-m-thick) poorly-sorted, pebble- to cobble-size conglomerate composed exclusively of Childs Latite (Tcl) clasts. Flows are porphyro-aphanitic with < 2-cm-long phenocrysts comprising 15% of rock. Most abundant phenocrysts are euhedral laths of zoned plagioclase (labradorite) and subhedral to euhedral, usually glomeroporphyritic, augite. Oxyhornblende and biotite (partially to completely oxidized to magnetite and hematite) are minor constituents, and euhedral apatite is an accessory phase. Pilotaxitic groundmass consists of plagioclase microlites, clinopyroxene, disseminated magnetite, hematite, and interstitial cryptofelsite. Vesicles and microveinlets are lined or filled with calcite or cristobalite and tridymite.
**Tcb - Childs Latite and coeval plutonic rocks, olivine-augite basalt and alkali basalt (middle Miocene)**

Brown, gray, and black olivine-augite basalt, augite basalt, and alkali olivine basalt flows, flow breccias, and less common plugs and dikes. Weathered surfaces are darker and black-, brown-, tan-, and gray-mottled. In the southern Ajo Range, individual flows are 5- to 20-m-thick (unit <100-m-thick); farther north, individual flows are <2-m-thick (unit <10-m-thick); dikes <3-m-thick. Flows are dense, massive to flow-banded, porphyritic, and vesicular; usually lenticular in cross section and laterally discontinuous. Flows commonly have red-brown, scoriaceous basal agglomerate, and flow tops bear slightly flattened vesicles. Phenocrysts compose 5-15% and include euhedral to subhedral, partially- to totally- iddingsitized olivine (0.5- to 1-mm), green, euhedral to subhedral, twinned augite (<2 mm), and less common moderately-zoned, locally glomeroporphyritic plagioclase (labradorite) (<4 mm). Hypersthene, magnetite, and apatite occur as rare accessory minerals. Groundmass is pilotaxitic and composed of plagioclase microlites and laths, intergranular clinopyroxene, olivine (commonly iddingsitized), secondary chlorite, magnetite, minor brown, partially-devitrified glass, and minor calcite in veinlets and vesicles. K-Ar whole-rock age-dating and regional stratigraphy indicate an age of greater than 18 Ma for a flow in the northern Ajo Range (Tosdal, unpub. data, 1983).

**Tcm - Childs Latite and coeval plutonic rocks, monzogranite of Siovi Shuatak Wash and related rocks (middle Miocene)**

Heterogeneous mixture of monzogranite, monzogranite porphyry, and minor monzonite porphyry. First informally described by May et al. (1981). Fresh surfaces are gray, pink, purple, or red; weathered surfaces are mottled shades of gray, green, brown, white, tan, and orange. Contacts with Childs Latite (Tcl) are complex and intrusive, suggesting the two units are coeval. Extremely variable textures include microcrystalline or cryptocrystalline and porphyritic to granitoid. Intrusive breccias and thin, interfingered dikes are common. Phenocrysts include euhedral, potassium-rimmed andesine (1 cm long). Groundmass is fine- to medium-grained and composed of subhedral plagioclase, anhedral orthoclase, augite, biotite, hornblende, interstitial quartz, and disseminated magnetite. Accessory minerals include sphene and apatite. Argillic alteration and silification is locally pervasive; plagioclase is altered to sericite and clay minerals, mafic minerals altered to magnetite, chlorite, epidote, and calcite. Confined to the Ajo Range.

**Rhyolite of Pinkley Peak**

Silicic volcanic and sedimentary rock sequence stratigraphically subjacent to, and unconformably overlain by, Childs Latite (Tcl). Includes rhyolite, rhyodacite, and dacite flows, domes, and tuffs, as well as minor andesite and basalt flows with interbedded sandstone and conglomerate. The Rhyolite of Pinkley Peak was informally named and first described as the Ajo volcanic field basal unit in the Puerto Blanco Mountains (Miller et al., unpub. data, 1984; Tosdal et al., 1986). Later, the unit was extended to include rocks of similar lithology and stratigraphic position in the Gunsight Hills and in isolated exposures in the northernmost Ajo Range. K-Ar ages indicate that volcanism occurred 22-18 Ma (Tosdal and Miller, unpub. data, 1983). Petrographic characteristics include (1) plagioclase phenocrysts (commonly sieve-textured with inclusions of partly-devitrified glass and apatite), biotite, oxyhornblende, hypersthene, augite, and rare quartz and sanidine and (2) a groundmass consisting of flow-banded glass, partly recrystallized to microcrystalline quartz, feldspar, magnetite, and clay minerals.

**Tpb - Rhyolite of Pinkley Peak, olivine-augite basalt dikes (lower Miocene)**

No additional description provided.
Tpr - Rhyolite of Pinkley Peak, biotite rhyolite domes, flows, agglomerates, and tuffs (lower Miocene)

Gray domes characterized by a massive interior and contorted flow banding along the margins. Short, thick, stubby flows differ considerably in thickness, lateral extent, texture, and phenocryst content. Commonly porphyritic with phenocrysts of subhedral red-brown biotite, euhedral sanidine, solitary or glomeroporphyritic plagioclase (commonly enclosing euhedral apatite or sphene), and quartz. Groundmass is composed of devitrified glass and spherulites. Agglomerate is composed of monolithic angular to subangular cognate clasts in a gray, tuffaceous matrix, is poorly-sorted, and forms a carapace along flow and dome margins. Associated tuffs are lenticular and discontinuous. K-Ar sanidine dates yielded an age of 18.7 + 0.5 Ma (Gray et al., 1984).

Tprd - Rhyolite of Pinkley Peak, rhyolite, rhyodacite, and dacite flows, flow breccias (lower Miocene)

Gray, black, or brown, typically flow-banded to intergranular. Includes minor unmapped lithic lapilli tuffs (Tpt) and sheared (or otherwise disrupted) flow rocks with pervasive fault gouge. Minor phenocrysts commonly form either of two mineral assemblages: (1) euhedral augite, hypersthene, biotite, glomeroporphyritic plagioclase and hornblende (?) or (2) fragmental to glomeroporphyritic plagioclase, biotite, rare quartz, sanidine, and hornblende (?). Plagioclase is zoned with partially-resorbed cores. Groundmass is hyalopilitic, recrystallized groundmass contains spherulites; perlitic cracks are abundant. K-Ar biotite ages range from 22.4-20.5 Ma, and were obtained from several flows (Tosdal, unpub. data, 1983).

Tpt - Rhyolite of Pinkley Peak, lithic lapilli tuff (lower Miocene)

White to yellowish-green, poorly-sorted massive to well-bedded, commonly cross-bedded. Individual beds are 1cm- to 1-m-thick. Composed of fragmental plagioclase and biotite phenocrysts, subrounded lithic fragments of augite andesite (Tpa), and pumice lapilli (<1-cm-long) in a vitroclastic matrix. Matrix and lapilli composed of devitrified to brown clay minerals, yellowish-green celadonite (?), and zeolite (?) minerals. Interbedded with rhyolite, rhyodacite, and dacite flows (Tprd) and hornblende dacite (Tphd).

Tpd - Rhyolite of Pinkley Peak, dacite agglomerate (lower Miocene)

Medium-gray clasts of hornblende dacite in a fine-grained, red-brown, tuffaceous matrix. Petrography suggests dacite agglomerate may be a hornblende dacite facies (Tphd).

Tphd - Rhyolite of Pinkley Peak, hornblende dacite flows and agglomerate (lower Miocene)

Red-brown and gray hornblende dacite flows or gray clasts of hornblende dacite in fine-grained, red-brown, tuffaceous matrix. Phenocrysts include subhedral to euhedral oxyhornblende, zoned plagioclase (andesine to oligoclase, commonly bearing apatite prisms), and hypersthene (?). Groundmass is hyalopilitic with abundant magnetite. Petrographically similar agglomerate contains phenocrysts of euhedral oxyhornblende, less abundant subhedral plagioclase, and hypersthene (?) in a hyalopilitic groundmass of plagioclase microlites, dusty Fe-Ti oxides, and glass.

Tps - Rhyolite of Pinkley Peak, arkosic and volcaniclastic sandstone (lower Miocene)

Beige, tan, and red-brown, well-bedded, moderately-indurated arkosic and volcaniclastic sandstone and pebble conglomerate. Unit is interbedded with hornblende dacite (Tphd) and augite andesite (Tpa)
Pebbles are predominantly subangular clasts of the Gunsight Hills Granodiorite (Kgg) and less commonly andesite. Well-bedded; individual strata are between to 0.1- and 0.5-m-thick.

**Tpa - Rhyolite of Pinkley Peak, augite andesite (lower Miocene)**

Maroon, red-brown, and gray augite andesite flows. Phenocrysts composition includes glomeroporphyritic, euhedral plagioclase, subhedral augite, sparse biotite, and magnetite (subhedral crystals or rims on or replaces mafic phenocrysts). Pilotaxitic groundmass is composed of plagioclase microlites, augite, rare partially-devitrified, brown volcanic glass, and magnetite.

**Tvu - Volcanic and volcaniclastic rocks, undivided (upper Oligocene to lower Miocene)**

In the northwestern part of the Growler Mountains, unit is composed of porphyritic, light-pinkish-tan andesite and related volcaniclastic rocks. Andesite contains 35-40% euhedral to subhedral plagioclase laths (2-3 mm) and square-shaped crystals. Other phenocrysts include pleochroic pale-green to reddish-brown biotite (1-2 mm), diplosidic augite (1-1.5 mm), and minor hornblende, olivine, and orthopyroxene. Groundmass consists of abundant glass (>50%) and iron oxide. A few flows are holocrystalline. Olivine and other mafic minerals are ubiquitously altered. The unit underlies Childs Latite (Tcl) and Daniels Conglomerate (Tdc); possibly correlative with the Sneed Andesite. A K-Ar biotite date yielded ages between 21.8+0.7 and 22.0 +0.7 Ma (Miller, unpub. data). In the Little Ajo Mountains, flow rocks and pyroclastic tuffs are purplish-brown to bluish-gray, porphyritic, with biotite, hornblende, and plagioclase phenocrysts. K-Ar determination on biotite yielded an age of 23.8+0.8 Ma (Gray and Miller, 1984). Whole rock age date of 25.2+2.2 Ma was obtained by type locality at Ajo Peak (Eberly and Stanley, 1978). In southern ORPI near Mexican/American border, the unit is mapped as pyroclastic rocks of intermediate composition. (unit Ta, unit Tav, unit Tvi).

**Tlc - Locomotive Conglomerate (Oligocene)**

Coarse to very coarse, reddish-brown rocks composed of poorly-sorted, subangular to subrounded, crudely-bedded clasts in a well-cemented, reddish (oxidized), sandy matrix. Clasts are mainly unroofed basement rocks. Informally named Locomotive Fanglomerate by Gilluly (1946). Age is Oligocene and/or early Miocene. (unit Tl).

**Tss - Syenogranite porphyry phase dikes of Granite of Schuchuli (upper Oligocene)**

No additional description provided.

**Tgsa - Granite of Schuchuli, biotite alaskite porphyry (upper Oligocene)**

Alaskite porphyry – grayish- and pinkish-tan, fine-grained, biotite alaskite porphyry. Composed of phenocrysts of subhedral to euhedral albite, embayed quartz, subhedral cloudy orthoclase, and subhedral biotite in a groundmass of orthoclase and quartz. Granophyre and, locally, albite phenocrysts are rimmed by micrographic quartz and orthoclase. Micrographic quartz and orthoclase compose as much as 30% of the groundmass and increase in abundance toward the north where alaskite porphyry becomes micrographic alaskite porphyry. Euhedral sphene, apatite, and zircon are accessory minerals. Mioalbitic cavities, as much as .25 cm in diameter, also increase in abundance toward the north. Sparse pegmatite pods are gradational and as much as 5 cm in diameter. (units Tsm and Tsa).
**Tgl - Granite and monzogranite (upper Oligocene)**

Fine-grained, allotriomorphic granular quartz, K-spar, plagioclase, and biotite aggregate.

**Td - Tertiary dikes, undivided (Tertiary)**

Includes Tertiary dike plugged faults, and diabase dikes.

**TKgs - Granite of Senita Basin (Late Cretaceous to Early Tertiary)**

White to gray, pink, or greenish, leucocratic, moderately-peraluminous garnet two-mica granite. Two mesoscopically distinct phases: (1) Older biotite- or (less commonly) muscovite-biotite-bearing syenogranite; medium- to coarse-grained, pink to reddish weathering, generally equigranular but locally porphyritic (with microcline megacrysts <1 cm), and (2) younger muscovite- and garnet-bearing microcline granite: very fine- to medium-grained, highly leucocratic (white weathering), unfoliated to subtly foliated. Typically marginal to older phase and far more common occurs as dikes and sills in schistose aureole. Garnet-bearing dikes commonly intrude older phase and locally grade into pegmatite and muscovite pegmatite (10- to 40-cm-thick, dipping 60o or more). Granite post-metamorphically intrudes metaquartz porphyry, forming an aureole of foliated, quartzofeldspathic schists (KJmv).

**TKc - Comelia Quartz Monzonite (Late Cretaceous to Early Tertiary)**

Granodiorite porphyry typically altered and mineralized. Porphyry grades into equigranular granodiorite north of the Cornelia mine pit. Includes a fine-grained diorite border phase present on the east side of Camelback Mountain.

**Gneiss of Chagit Vo**

Gneissic or mylonitic rocks derived from various phases of granodiorite of Gunsight Hills (Kgg). Changes in fabric orientation and metamorphic grade suggest that these rocks are part of an originally gently dipping ductile shear zone (Ramsay, 1980). Metamorphic grade increase from northwest to southeast, highest grade gneiss yields K-Ar minimum ages of 59.4 Ma (hornblende) and 32.3 Ma (biotite) (Haxel et. al., 1984). Consists of 4 facies: blastomylonitic granodiorite gneiss (TKcb), granodiorite gneiss (TKcg), blastomylonitic monzogranite gneiss (TKcm), and protomylonitic granodiorite gneiss (TKcp).

**TKcb - Gneiss of Chagit Vo, blastomylonitic granodiorite gneiss (Late Cretaceous to Early Tertiary)**

Gray to green, pinkish weathering, medium- to fine-grained. Mica, feldspar, and quartz define lineation and form augen in blastomylonitic fabric.

**TKcg - Gneiss of Chagit Vo, granodiorite gneiss (Late Cretaceous to Early Tertiary)**

**TKcm - Gneiss of Chagit Vo, blastomylonitic monzogranite gneiss (Late Cretaceous to Early Tertiary)**

Gray to pinkish, yellowish to orange-gray weathering, leucocratic, medium- to fine-grained. Monzogranite gneiss contains fragmented blastophenocrysts of microcline (>1 cm diameter) and plagioclase in blastomylonitic to lepidoblastic matrix (quartz, feldspar, mica, epidote, rare hematite).

**TKcp - Gneiss of Chagit Vo, protomylonitic granodiorite gneiss (Late Cretaceous to Early Tertiary)**

Gray to greenish, varies from relatively undeformed granodiorite to penetratively deformed and recrystallized protomylonitic gneiss. Relict igneous textures discernible. Strongly recrystallized quartz and biotite with white mica define foliation.

**Kgb - Bandeja Well Granodiorite (Late Cretaceous)**

Gray, leucocratic, hornblende-bearing biotite granodiorite, biotite monzogranite, aplite porphyry, and uncommon sphene diorite and biotite-hornblende quartz monzonite. Texture varies from porphyritic to hypidiomorphic-granular to equigranular. Phenocrystals include oligoclase, plagioclase, orthoclase, quartz, hornblende, and biotite. Characteristic oligoclase phenocrysts (<1 cm-across) are subhedral to euhedral, exhibit weak oscillatory zoning, and are locally myrmekitic. Plagioclase is locally moderately-altered to white mica and epidote or saussurite. Orthoclase is anhedral, poikilitic, weakly perthitic, (~20 mm-across), partly altered to clay minerals, and exhibits a reaction rim of myrmekite when in contact with oligoclase. Quartz is anhedral to rarely subhedral, usually strained, and exhibits minor recrystallization. Sparse hornblende is subhedral to euhedral. Biotite is subhedral to euhedral and occurs in long, columnar blocks. Both hornblende and biotite have been deuterically altered to chlorite. Accessory phases include iron oxide (magnetite?), sphene,apatite, and zircon.

**Kap - Ajo pluton, granitic rocks and metavolcanic schist, undivided (Late Cretaceous)**

Mixed zone of granitic rocks and metavolcanic schist.

**Kgg - Gunsight Hills Granodiorite and related rocks (Late Cretaceous)**

(~67 Ma) Gray to pinkish-gray or tan, medium-grained, hypidiomorphic-granular or porphyritic hornblende-biotite granodiorite, with subordinate biotite leucogranodiorite, biotite granite, and aplite. Granodiorite commonly exhibits microscopic recrystallization and deformation textures and contains phenocrysts of orthoclase/microcline or oligoclase. Phenocrysts include alkali feldspar, plagioclase, quartz, epidote, white mica, biotite, and hornblende. Alkali feldspar is pinkish-white, microperthitic, and varyingly altered to clay minerals. Plagioclase is white and commonly altered to white mica and epidote. Quartz is anhedral and interstitial, usually strained, and locally recrystallized near crosscutting veins (filled with gray to white massive quartz, lesser epidote, and white mica). Biotite is locally kinked and varyingly altered to limonite or (less commonly) to chlorite, sphene, and white mica. Sparse euhedral hornblende is altered to limonite. Accessory minerals include sphene, apatite, and zircon. The unit is locally intruded by biotite monzogranite, aplite dikes, and altered hypabyssal plagioclase porphyry dikes. U-Pb ages from zircon indicate a late Cretaceous age (Tosdal, unpub. data, 1985) for the granodiorite; previously reported K-Ar ages (Shafiqullah et al., 1980; Tosdal, unpub. data, 1983), ranging from 47 to 36 Ma, relate to uplift and cooling in Eocene time.
Kga - Aguajita Spring Granite (Late Cretaceous)
(~80 Ma) Weathered white to cream, highly leucocratic, foliated, variably cataclased and recrystallized, locally protomylonitic (less commonly equigranular), biotite monzogranite. Microcline megacrysts (<3 cm) are typically perthitic, euhedral, and white. Original microcline phenocrysts are augen-shaped porphyroclasts in a quartzofeldspathic matrix. Unit is cut by pegmatite and aplite dikes resembling those found in adjacent gneiss (Pgm). Biotite granite is foliated against the Proterozoic gneiss (Pgm) but does not intrude it. Age of unit is according to Anderson and Roldan-Quintana (1979).

Kvu - Cretaceous volcanic rocks, undivided (Late Cretaceous)
In the southern Growler Mountains: Light gray to greenish-gray to pinkish-gray silicified metarhyolite to meta-andesite flows and tuffs. Now consists of secondary minerals including albite, sericite, chlorite, quartz, and plagioclase. Minor minerals include hornblende and orthoclase and primary apatite, zircon, sphene, and magnetite. Lithology unknown elsewhere.

KJc - Conglomerate at Scarface Mountain (Late Jurassic to Early Cretaceous)
Well-indurated, poorly-bedded to massive conglomerate and intermediate to silicic volcanic flows and pyroclastic breccia with sparse interbeds of conglomeratic sandstone. Conglomerate and lithic-rich breccia contain subangular to subrounded pebbles and cobbles of granite (Pgm, Ycs), calc-silicate granofels, marble, and quartzite. Unit is locally intruded by thick rhyolitic dikes with vitrophyric margins; hornfelsic where cut by thin granitic dikes. Exposures limited to small isolated hills that rise above gravel surfaces along the south margin of Growler Mountains.

Rocks of La Abra
Middle to Late Jurassic protolith. Latest Cretaceous to early Tertiary and/or Jurassic metamorphism.

Jag - Rocks of La Abra, greenschist and metaconglomerate (Late Jurassic)
Green, biotite-epidote-chlorite schist and metaconglomerate. Contains oligoclase porphyroclasts (<1.5 mm) and lithic clasts (<50 cm) composed of quartz metaporphphyry and intermediate to silicic volcanic rocks, in a fine-grained epidote-rich matrix. Protolith may have been an andesitic or basaltic mudflow. In the Agua Dulce Mountains and western Puerto Blanco Mountains: Metagranite and metagranodiorite – Metamorphosed granitoid rocks, variably cataclastically deformed. Derived largely from granite (Jgr) and granodiorite and diorite (Jgd). Unit occurs in Puerto Blanco Mountains and Quitobaquito Hills.

Note: As the unit is largely derived from units Jgr and Jgd, this unit must be younger than these units. As the unit is listed as Jurassic in age, but younger than Late Jurassic units Jgr and Jgd, this unit must also be Late Jurassic in age.

Jgrr - Rocks of La Abra, intrusive rhyolite related to Jgr (Late Jurassic)
Aphatic, felsic hypabyssal rock which forms lenticular bodies within and is presumed to be late-phase crystallization of granitoid rocks (Jgr).

Jgr - Rocks of La Abra, heterogeneous, altered granitic rocks (Late Jurassic)
Fresh surfaces are pink to red, purple or gray; weathered surfaces are white, red, green, or brown; highly leucocratic, aplitic to coarse-grained, generally equigranular, unfoliated to weakly-foliated.
Phenocrysts include oligoclase, muscovite, and biotite. Granitic composition ranges from monzogranite to syenogranite or microcline granite with subordinate hornblende quartz diorite. May be protomylonitic and grade into ultramylonite toward the contact with Quartzofeldspathic semischist and phyllite (Jas). Intrudes granodiorite (Jgd) and is intruded by rhyolite (Jgrr) and dikes of undetermined composition. The unit may include metamorphosed rocks and rhyolite (Jgrr) not separately mapped. Found in the Puerto Blanco Mountains and Quitobaquito Hills.

**Jga - Rocks of La Abra, granite of Agua Dulce Mountains (Late Jurassic)**
Weathered purple, brown, or black, leucocratic to melanocratic, cataclasized, porphyritic biotite granite. May be related to granitoid rocks (Jgr).

**Jgd - Rocks of La Abra, granodiorite and quartz diorite (Late and/or Middle Jurassic)**
Fresh surfaces are pink to red; weathered surfaces are pink to brown; leucocratic, unfoliated felsic plutonic rocks. Includes equigranular to porphyritic, very fine- to coarse-grained biotite, granodiorite, and hornblende diorite, coarse-grained plagioclase-biotite diorite, and medium-grained equigranular hornblende monzonite. Unit crops out in the Puerto Blanco Mountains, Quitobaquito Hills, and Agua Dulce Mountains.

**Japs - Rocks of La Abra, quartzofeldspathic phyllite and semischist (Jurassic)**
Gray, tan- to orange-weathering, highly leucocratic, very fine to fine-grained, locally lineated quartzofeldspathic schist in dynamothermal aureole of Granite of Senita Basin (TKgs). Metavolcanic, probably metaarhyolite derived largely from quartz porphyry. Unit also includes subordinate quartz-rich gneiss or micaceous quartzite (moderately to locally weakly foliated), with intrafolial biotite schist or metagranite porphyry. Variable texture of metavolcanic schist is inequigranular, coarsely porphyroelastic, prophyroelastic, or xenoblastic. Forms knobby to angular outcrops with moderately developed foliation fracture. Contact with Granite of Senita Basin (TKgs) is gradational. Locally a gray, mesocratic, metadiorite, or dark biotite-rich quartzofeldspathic schist may be found parallel to the foliation in direct contact with the Granite of Senita Basin.

**Jap - Rocks of La Abra, Pozo Nuevo Granite Porphyry (Jurassic)**
Leucocratic to mesocratic, weathered greenish-gray to brown, variably metamorphosed biotite granite porphyry and porphyritic biotite granite. Essentially unmetamorphosed to slightly foliated, locally strongly foliated. Variably mylonitized, with a coarse-grained texture, feldspar-porphyroelastic to inequigranular and unlined. The unit has various subunits distinguished by relative size of white to pink feldspar porphyroclasts. Phenocrysts include euherdal to subhedral perthitic microcline (<1 cm), sericitized oligoclase, and polycrystalline quartz. Fine-grained matrix has the same assemblage. The unit is commonly intruded by 20-m-thick aplite dikes). Granite has a detachment (or slide) contact with the underlying metaquartz porphyry (Jaq) and chlorite schist (Jas), thin, unmapped slide sheets of porphyry and schist are included at the base of the upper slide sheet of the Pozo Nuevo Granite Porphyry, which tends to be ultramylonitic along fault boundaries (Haxel et al., 1984). Found in the Puerto Blanco Mountains and Quitobaquito Hills.

**Jaq - Rocks of La Abra, metamorphosed quartz porphyry (Jurassic)**
Weathered green, gray, white, brown, or buff, usually leucocratic, very fine-grained, metamorphosed quartz porphyry derived from silicic (?) volcanic and volcaniclastic, hypabyssal, and sedimentary protoliths (~160 Ma). Unit also contains minor mica-poor quartzofeldspathic paraschist, phyllite, and greenschist. Generally schistose, variably foliated to mylonitic, and isoclinally folded and lineated.
Main porphyroblastic phases are feldspar (2-10%) and less commonly quartz (both <1 cm). Metamorphosed quartz porphyry has a dark and light variety. The dark variety (gray) is blastomylonitic, with pseudohexagonal biotite, chlorite, and lesser muscovite. The light variety (white, silver, or tan) tends to have quartz (<3 mm) in a fine-grained matrix containing relict hornblende, biotite, quartz, oligoclase, and orthoclase. The unit is hematite-stained and silicified where it has been hornfelsed by the Granite of Senita Basin (TKgs), grades up-section (southward) from blastomylonite to fissile schist, and is largely metavolcanic, with subordinate meta-intrusives. Outcrops are typically blocky and may include interfoliated, 10-m-thick layers of quartzofeldspathic paraschist (?) or greenschist of mafic origin; both are more strongly metamorphosed, metamorphism predates that of the main unit. Found in the Puerto Blanco Mountains and Quitobaquito Hills, usually in low-lying flats, especially where strongly folded and deformed.

**Jas - Rocks of La Abra, quartzofeldspathic semischist and phyllite (Jurassic)**

Composed of two lithologic subgroups not separated on the map (see Haxel et al., 1984; Gray et al., 1988). (1) Predominant sericite-quartzofeldspathic semischist and lesser phyllite (calcareous in part), with subordinate metaconglomerate and marble; weathered gray, purple, red, brown, or black; very fine- to medium-grained, equigranular to slightly porphyritic; may be mylonitic. (2) Chlorite schist; weathered dark green; fine- to medium-grained, bears quartz phenocrysts and platy chlorite (derived from biotite); may be mylonitic. Unit found in the Puerto Blanco Mountains and Quitobaquito Hills.

**TRYXo - Orthogneiss and foliated granite (Triassic? Mesoproterozoic? Paleoproterozoic?)**

Consists of a variety of gneissic lithologies listed below from oldest to youngest: (1) layered biotite quartzofeldspathic schists and gneisses, (2) hornblende-biotite augen gneiss, (3) granitic, typically highly leucocratic gneiss, (4) amphibolite gneiss, and (5) biotite aggregate (spotted granitoid gneiss).

**MDm - Escabrosa and Martin Formations (Mississippian and Devonian)**

Marble calcsilicate rocks.

**Cs - Bolsa and Abrigo Formations (Cambrian)**

Quartzite and carbonate (respectively).

**Ycs - Chico Shunie Quartz Monzonite (Mesoproterozoic)**

Quartz monzonite is the dominant rock type of this unit, however minor albite granite, quartz diorite, and trondhjemitic are associated temporally. Most common variety of quartz monzonite is pinkish-gray to slightly foliated or massive and coarsely porphyritic. Consists of euhedral to rounded feldspar phenocrysts (2-3 cm). The groundmass is composed of quartz, biotite (altered to chlorite), altered feldspar, and minor epidote and muscovite. Accessory minerals include magnetite, apatite, zircon, and sphene. Unit forms gently rolling hills in the eastern part of the Growler Mountains around Tepee Butte and Chico Shunie Arroyo; intrudes Cardigan gneiss crosscutting foliation. The Chico Shunie was considered to be Mesozoic age by Gilluly (1937), however a K-Ar amphibole date from a pegmatite dike cutting the main Chico Shunie body yielded an age of 1400 Ma (Tosdal, oral communication, 1980); the age of the Chico Shunie is therefore reassigned to the Precambrian.

**Xcg - Cardigan Gniess (Paleoproterozoic)**

Includes medium-grained irregularly-banded gneiss, fine-grained gneiss, minor augen gneiss, albite-schist and sericite-quartz schists, and quartz-diorite gneiss. Medium-grained gneiss is dark- to
medium-gray and consists of plagioclase, quartz, chlorite, biotite, and muscovite; textures are predominantly crystalloblastic with minor cataclastic zones. Finer-grained gneisses consist of 35% hornblende, 45% plagioclase, 10% quartz, 5% orthoclase, and accessory ilmenite, magnetite, apatite, epidote, chlorite, augite, and biotite; textures are mainly granulitic; plagioclase is commonly altered to aggreagates of sericite, epidote, and saussuritized albite. Quartz forms approximately 35-50% of the rock, plagioclase 21-49%, chlorite 15%, biotite 4%, and accessory amounts of K-spar, sphene, ilmenite, magnetite, calcite, and apatite. The Cardigan Gneiss has undergone at least two stages of pervasive deformation: (1) regional deformation of dioritic intrusives creating foliation and a general gneissic-banded appearance and (2) injection of feldspathic material accompanied by ptygmatic folding. Cardigan Gneiss is intruded by Chico Shunie Granite (Ycs). Assigned to the Precambrian(?) by Gilluly (1946), but it is here in considered Proterozoic on the basis of correlation with the Pinal Schist (dated at 1700 Ma, Tosdal, written communication).

Xp - Pinal Schist (Paleoproterzoic)

(~1700 Ma) Fine- to medium-grained biotite and/or muscovite quartz-feldspathic schist, with a generally strong foliation coincident with lithologic layering and a penetrative lineation in the plane of foliation. Locally includes minor Pioneer shale.
Ancillary Source Map Information

The following section presents ancillary source map information associated with the source used for this project.

Organ Pipe Cactus National Monument (Geological Reconnaissance)

The formal citation for this source.


Prominent graphics and text associated with this source.

Correlation of Map Units
Unit K??? has been renamed to Kap in the GRI digital geologic GIS data. A few units present in the data are not present in the above unit correlation.

Graphic from source map: Organ Pipe Cactus National Monument (Geological Reconnaissance)

Geologic Units of the Organ Pipe-Pinacate Region

Principal rock units: lithology; distribution; age

- Alkali basalt flows, tuffs, cinder cones, and maars; Pinacate volcanic field; 2 – 0 Ma
- Latite, andesite, and rhyolite flows, flow breccias, subvolcanic intrusions; Ajo volcanic field; Miocene, 23 – 14 Ma
- Andesite, dacite, granodiorite, granite, porphyry (with local associated Cu deposits); widespread, including Ajo area, Quitobaquito Hills, Sonoyta Mountains, Pinacate–Cabeza Prieta region; 80 – 50 Ma
- Metaconglomerate; near Growler Pass
- Diverse volcanic, volcanioclastic, and granitic rocks, variably metamorphosed; widespread, including Puerto Blanco Mountains, Quitobaquito Hills, many ranges in northern Sonora; Jurassic, 180 – 145 Ma
- Monzonitic granitoids and derivative gneisses; near Sonoyta; Triassic, 230 Ma
- Naco Group strata probably once present, but eroded before Jurassic time
- Marble and calcisilicate rock, derived from Martin (Devonian) and Escabrosa (Mississippian) Formations; near Growler Pass
- Not deposited in southern Arizona region
- Quartzite, hornfels, and schist, derived from Bolsa Formation and overlying Abo Formation; near Growler Pass
- Apache Group strata and associated diabase (1100 Ma) not exposed, but possibly present or once present
- Granite; Chico Shunie Hills, Pinacate region; 1400 Ma
- Gneisses and granitoids; Ajo area, Quitobaquito Hills, Pinacate region, Sonoyta area; 1750 – 1600 Ma
- Formation of continental crust of Southwest North America: 2000 – 1800 Ma
- Oldest rocks preserved on Earth, 4000 Ma
- Origin of Solar System, including Earth

Graphic from source map: Organ Pipe Cactus National Monument (Geological Reconnaissance)
Geological Report on Organ Pipe Cactus National Monument, ORPI, and Surrounding Region

Overview of Main Rock Units and Regional Geologic History
Organ Pipe Cactus National Monument (ORPI), Arizona, protects part of the Sonoran Desert in southern Arizona, along the U.S. border. The park is characterized by northwest-southeast trending mountain ranges, separated by broad alluvial plains typical of the Basin and Range Province in the desert southwest. Rocks exposed in and around ORPI record 1.8 billion years of the Earth’s history. The park encompasses a diverse suite of rock lithologies, geologic resources, and unique morphologic features, all of which result in a complex geologic history. For example, active alluvial fans (concentrated in the valley of Ajo) support dense stands of vegetation important to local wildlife, widespread granitic intrusions and felsic volcanism of the Ajo Range are valuable resources for ore mining, and Quitobaquito Springs provides a rare perennial water source produced, in part, by an impervious fault zone along the southwestern flank of the Quitobaquito Hills (Bezy et al., 2000).

Due to the long and complex geologic history of this region (Fig. 1), we present herein a simplified overview of the five geologic events that helped shaped the landscape: (1) Early to Middle Proterozoic crustal formation, (2) Paleozoic deposition of marine to marginal marine sedimentary rocks, (3) Jurassic and Early Cretaceous igneous intrusions, volcanic activity, and deformation, (4) Late Cretaceous and Early Tertiary igneous intrusions accompanied by widespread metamorphism and contractional deformation during mountain building, and (5) Neogene (Miocene to Quaternary) volcanism and extensional deformation that lowered the landscape. With each major geologic event, we will first provide regional context of the rocks and events of that age, a brief description of rock types, and other pertinent summary information. A complete description of rock units can be found in the latter portion of this report.

1) Proterozoic: Continental Crust Formation and Mountain Building

The oldest rocks in the map area are 1700 to 1600 Ma schists (Xp), gneisses (Xcg), and monzonites (Ycs) exposed within the Chico Shunie Hills east of the Growler Mountains and orthogneiss and granite (TRYXo) of undetermined age exposed within the Quitobaquito Hills. Combined, these rocks represent early to middle Proterozoic continental crust formation and mountain building. Transcontinental Proterozoic provinces span from Southern California to the Great Lakes, and comprise two belts, the outer and inner, that were added to North America. ORPI is located within the outer accretionary belt, which was added to North America during the Yavapai and Mazatzal orogenies (Van Schmus et al., 1993). The Yavapai Orogeny (1710-1680 Ma) involved the Mojave and Yavapai microcontinents obliquely colliding with the North American craton (today’s Colorado and Wyoming) (Karlstrom and Bowring, 1988). The Mazatzal Orogeny (1660 -1640 Ma) was the collision of an unknown arc or continent with North America from the south that created northwest-directed contractional deformation and a major continental arc spanning from California to eastern Canada (Karlstrom and Bowring, 1988; Van Schmus et al., 1993).

2) Paleozoic: Shallow Sea Transgression

Given that south-central Arizona was part of the North American continent by Middle Proterozoic time, Paleozoic sedimentary rocks deposited in ORPI were likely part of the typical continental sequences found elsewhere in the southwest. Although complete sections of sedimentary deposits from the Paleozoic continental margin and shelf are exposed in most of Arizona, especially on the Colorado Plateau, exposures of Paleozoic sedimentary rocks within the ORPI map area are limited to the eastern Growler Mountains just north of Growler Pass. The Escabrosa and Martin Formations (MDm) are Devonian and Mississippian carbonates deposited during a series of marine transgressions (Beus, 1989). The Bolsa and Abrigo Formations (Cs) are Cambrian quartzite and carbonate rocks (respectively) likely deposited in an intertidal or shallow subtidal environment based on better exposed sections in southeastern Arizona (Middleton, 1989).
3) Jurassic to Early Cretaceous: Igneous Intrusions, Volcanic Activity, and Deformation

Middle to late Jurassic volcanic and plutonic rocks comprise the bulk of rocks exposed in ORPI and surrounding areas, and they are the product of a northwest-trending continental-margin magmatic arc resulting from oblique subduction of the oceanic Farallon (and other) plates beneath the overriding North American plate (Tosdal et al., 1989). In the Middle to Late Jurassic, a system of sinistral strike-slip faults, known as the Mojave–Sonora Megashear, cut obliquely across the magmatic arc, producing an estimated 800 km displacement is some areas (Anderson and Silver, 2005). Widespread evidence in northern Mexico and southern Arizona suggests that the Megashear was active from 166-148 Ma. The main focus of the Megashear was across northern Mexico, but secondary structures (Quitobaquito Thrust) affected the western ORPI region, causing a series of thrust faults and metamorphism in the Quitobaquito Hills that involve Jurassic and possible Triassic rocks.

From Haxel, et al., 1984: The gently south-dipping Quitobaquito thrust places high grade (but partially retrograded), lithologically heterogenous Precambrian (?) gneisses and schists over lower-grade metamorphosed Jurassic supracrustal and intrusive rocks. Unlike the other thrust faults in south-central Arizona, which have single lower plates, the Quitobaquito thrust is underlain by a stack of some eight imbricate structural sheets separated by zones of mylonitic or ultramylonitic rocks. These structural sheets evidently for a duplex for which the Quitobaquito thrust is the roof thrust. A single blastomylonitic to, locally, mylonitic or crystalloblastic metamorphic fabric, with consistently oriented foliation and lineation, extends continuously from the lower part of the upper plate of the Quitobaquito thrust down through the entire several-kilometer thickness of imbricate lower-plate sheets. This tectonite fabrics is most strongly developed within the mylonitic zones bounding the sheets and decreases in intensity into the interiors of the sheets. As the contacts between sheets are syn-metamorphic or shear zones marked by intensification of the regional metamorphic fabric, they are best referred to as “tectonic slides,” following the definition of Hutton (1979). (No connection with gravitational sliding is inferred or implied).

During the Jurassic, arc-magmatism and granitic plutonism (Jga, Jgr, Jgrr, Jgd) produced the intrusive felsic volcanic rocks of the Puerto Blanco and Agua Dulce Mountains and the Quitobaquito Hills. Jurassic plutonic rocks were later variably metamorphosed possibly due to deformation related to the Megashear, producing a variety of meta-granites, phyllites, schists, and altered granitic rocks in this area (Jag, Japs, Jap, Jaq, Jas, Jgr). Metamorphosed conglomerates and breccias (KJc, Jag) near Growler Pass in the Growler Mountains represent sediments eroded from highland areas in the late Jurassic to early Cretaceous (150-140 Ma) (Bezy et al., 2000).

4) Late Cretaceous and Early Tertiary: Igneous Intrusions Accompanied by Widespread Metamorphism and Contractional Deformation

The convergent plate boundaries of the Mesozoic in western North America continued into the early Tertiary and eventually formed high mountains across the western USA. This setting was modified in the latest Cretaceous to early Tertiary (80 to 40 Ma) by the shallow-slab subduction of the Laramide belt, which was recently defined to include the Mojave of California to Colorado Plateau and Rocky Mountains of the interior continent (Saleeby, 2003). ORPI lies along the southeastern boundary of the classic Laramide belt, which has no arc of Cretaceous/Early Tertiary age. An 80-60 Ma arc was present, however, from the southern boundary of ORPI southeast into Mexico.

Metamorphic rock outcrops in this region are locally separated by broad expanses, and most of the areas with metamorphic rocks are relatively small. Metamorphic grades range from middle gneisschist to lower (?) amphibolites facies and garnet-two-mica granites (Tgs) commonly intrude metamorphic areas. Syn-metamorphic thrust faults place plutonic rocks or high-grade metamorphic basement rocks (TRYXo), over supracrustal rocks of lower metamorphic grade and other plutonic rocks. The common garnet-two-mica granitite plutonism and juxtaposition of metamorphic rocks via thrust faulting suggests that these events were related aspects of an deformation episode during the late Cretaceous and early Tertiary Laramide orogeny (Haxel et al., 1984). This Laramide-age deformation includes probable reactivation of the Quitobaquito thrust fault with the late Cretaceous
granite (Kga) thrust over Mesozoic rocks. Geochronologic data indicate that orogenesis commenced in Late Cretaceous (~80-70 Ma) and ended by the early Tertiary (~58-60 Ma).

5) Neogene (Miocene to Quaternary): Extension and Volcanism

Neogene lithospheric extension and magmatism formed the Basin and Range Province and overprinted earlier metamorphism and contractional deformation and lowered the previous mountains to the present elevation. The main belt of extension in Miocene time (~23 – 15 Ma) lies north of ORPI from west-central and northwest Arizona to Phoenix and Tucson (Spencer and Reynolds, 1989). ORPI is adjacent and south of this belt and had moderate extension and widespread volcanism at the same time. Neogene volcanic rocks near Ajo, Arizona form the Ajo Volcanic field and consist of (1) older, voluminous felsic lava flows, dikes, and associated pyroclastic rocks (Rhyolite of Pinkley Peak, Childs Latite, Rhyolite of Montezuma’s Head) and (2) younger basalt and basaltic andesite (Batamote Andesite Complex: 16 – 14 Ma). Isotopic ages from volcanic rocks of this event in ORPI are between 22 Ma and 14 Ma, although younger volcanic rocks lie outside the map boundaries (volcanic rocks in the Pinacate Volcanic field are a few million to a few thousand years old). Deformation and local volcanism in the past 15 Ma is related to the formation of the Gulf of California.

Ajo volcanic rocks overlap and are interbedded with clastic sedimentary rocks derived from underlying bedrock (Daniels Conglomerate (Tdc); sedimentary and volcanic rocks, undivided (Tsvu)), suggesting that volcanism and extension were synchronous at this time. A thick, eastward-thickening conglomeratic wedge in the Little Ajo Mountains, the Locomotive conglomerate (Tlc), records extensional basin formation that likely accompanied initial volcanism (Spencer et al., 1995). Normal faults that cut and tilt the volcanic sequences are abundant but have relatively small displacements.

Text from source map: Organ Pipe Cactus National Monument (Geological Reconnaissance)

References


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Text from source map: Organ Pipe Cactus National Monument (Geological Reconnaissance)
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