Compilation geologic map of the
Oracle 7 1/2' Quadrangle,
Pinal and Pima Counties, Arizona

by

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**COMPILATION GEOLOGIC MAP OF THE**

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**Introduction**

The Oracle 7 ½’ Quadrangle is located approximately 40 km north-northeast of downtown Tucson, and is on the northwest flank of Santa Catalina Mountains (Figure 1). The quadrangle encompasses the northwestern corner of the range, some of the flanking pediment around the town of Oracle, and alluvium in northeastern Oro Valley. The area was mapped during October 1999 to April 2000 as part of a multiyear mapping program directed at producing complete geologic map coverage for the Phoenix-Tucson metropolitan corridor. A 1:24,000 scale map is the primary product of this study (Plate 1). This map incorporates past mapping by other workers as well new mapping by the authors (Figure 2). The accompanying report describes rock units and other geologic features. This mapping was done under the joint State-Federal STATEMAP program, as specified in the National Geologic Mapping Act of 1992. Mapping was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey under STATEMAP Program Contract #99HQAG0171.

The bedrock geology of the map area is dominated by the 1.4 billion-year-old Oracle Granite and the ~24 million-year-old Catalina granite (Figure 3). These two granites are separated by a complex belt of diverse rocks that includes early Proterozoic Pinal Schist, middle Proterozoic Apache Group and intruding diabase, metamorphosed Cambrian sandstone, siltstone, and carbonate, and the intruding late Cretaceous to early Tertiary Rice Peak porphyry. Weakly consolidated Miocene conglomerate overlies some of these rocks, and the conglomerate and many older rocks are cut by the west-northwest trending, Oligo-Miocene (?) Mogul fault. The inactive, north-south trending, Miocene (?) to Pliocene Pirate fault projects northward through the northwestern corner of the map area where it is probably represented in the subsurface by a buried fault that places thousands of feet of fan gravels against bedrock. Earth fissures related to groundwater withdrawal in Oro Valley could develop in the future above the buried Pirate fault. The pediment that has developed over parts of the Oracle Granite represents a challenge to home builders because of the very shallow and largely impermeable bedrock in this area.

Historic copper production at the Little Hill mine, and more recent production of decorative stone, were both the result of mining and quarrying from altered rocks around the west end of exposures of the Mogul fault. A small granite body that is cut by the fault is probably responsible for the copper mineralization and possibly also some of the color development of the decorative stone.

Previous geologic studies in the Oracle 7 ½’ Quadrangle include detailed bedrock mapping by Erickson (1962) and Suennicht (1977), regional mapping by Budden (1975) and Force (1997), detailed mapping of the Pirate fault by Dickinson (1994), a detailed map and study of the Little Hill mine area by Durning (1972) and of the Catalina granite by Hoelle (1976), and a study of the geomorphology and soil development in the terraced valley in the southwestern corner of the quadrangle (McFadden, 1978, 1981).

**Acknowledgments.** We especially thank Dave McGee, President of Silica Mines, Inc., for allowing access to his properties in the Little Hill mine area and along the Cañada del Oro. This mapping study would not have been possible without such access. We also thank Dave McGee for information regarding the history of mining and quarrying in the Little Hill mine area. We also thank Phil Pearthree, Eric Force, Steve Skotnicki, and Bill Dickinson for discussions that were helpful in developing an understanding of the geology of the area.
Figure 1. Location of the Oracle 7.5' quadrangle.
Figure 2. Sources of map data

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Figure 3. Simplified geologic map of the Oracle 7 1/2’ Quadrangle.

Xp = Pinal Schist; Yom = mylonitic Oracle Granite; Yad = Apache Group and Sierra Ancha diabase; Cs = Cambrian metasedimentary rocks, undivided; TKr = Rice Peak porphyry; Ta = Little Hill alaskite; Tc = Tertiary conglomerate
Santa Catalina Mountains. The Santa Catalina Mountains form a prominent mountain range north of Tucson, Arizona, that consists of a great variety of rock types. The south flank of the range, known as the forerange, consists of banded, amphibolite-grade gneisses injected by granites of primarily Eocene age. These rocks are overprinted by a mylonitic fabric at high structural levels that was produced during mid-Tertiary tectonic exhumation of the range. These mylonitic fabrics mark the range as one of the many metamorphic core complexes in southwestern North America (Banks, 1980; Davis, 1980; Keith et al., 1980; Dickinson, 1991; Force, 1997). The north side of the range was largely unaffected by middle Tertiary mylonitic deformation, and lithologically diverse rocks of various ages are generally only slightly to moderately deformed and metamorphosed.

Mogul fault. The high-angle, west-northwest striking Mogul Fault cuts across the northernmost part of the Santa Catalina Mountains and places 1.4 Ga Oracle Granite north of the fault against a variety of rocks to the south (Figure 3), including ~1.7 Ga Pinal Schist, ~1.1-1.2 Ga sedimentary rocks of the Apache Group and intruding diabase, Paleozoic and Mesozoic strata, and local Tertiary conglomerate (note: Ga = giga annum = billion years old). The Mogul fault dips 80° to 85° to the south at the western end of its exposed trace. Fault dip appears to decrease eastward, with measured dips of ~30°-70°. Striations on slip surfaces in the fault zone plunge to the west near the Little Hill mine, but these were not measured due in part to their anastomosing and variable orientation. Rocks are extensively crushed and altered in the Little Hill mine area, but several kilometers to the east alteration is minor and fault zone crushing is restricted to a few-meter-wide zone along the fault.

Near the west end of the Mogul fault the Oracle Granite is intruded by a small granitoid body that was named the Little Hill alaskite by Durning (1972). Quartz veins that roughly parallel the Mogul Fault are common in the Oracle Granite over a distance of several hundred meters from the Little Hill alaskite, and a few are present up to several kilometers away. The alaskite and quartz veins, as well as host Oracle Granite, are mylonitized near the Mogul fault. Durning (1972, p. 16-17) recognized, and we confirm, that the mylonitic deformation of the Oracle Granite is associated with the Mogul fault and is better developed closer to the fault. As mapped in this study, the mylonitic fabric strikes parallel to the fault and dips 44° ± 9° (17 of 21 measurements are encompassed by this range) to the south. Mylonitic lineations plunge moderately to the southeast with a trend of 164° ± 18° (11 of 13 measurements are encompassed by this range). Asymmetric tails on porphyroclasts and S-C fabrics in the mylonitic rocks indicate a normal sense of shear during mylonitization (e.g., Hanmer and Passchier, 1991). Parallelism of the mylonitic fabric with the strike of the Mogul fault, the gradational increase in fabric development with greater proximity to the fault, and localization of the fabric to a 4.5 km long, 0.5 km wide belt directly adjacent to the fault, all support the interpretation that mylonitization was related to fault movement. Kinematic indicators in the mylonite suggest that fault movement at the time of mylonitization was normal, south-side down, with a component of left-lateral slip.

In one remarkable outcrop [located ~200 m N55°E from the 84° dip symbol (Plate 1) at the Little Hill mine] a dike of Little Hill alaskite that intrudes Oracle Granite, but is much less mylonitic than the host Oracle Granite, is folded into a tight fold with the mylonitic foliation approximately parallel to the axial plane of the fold. This fold is inferred to be a product of deformation within the mylonitic shear zone. Thin quartz veins that intrude the dike and cross the axial plane of the fold thicken in the hinge zone of the folded dike and reveal that vein emplacement occurred during folding, which occurred during mylonitization. These important relationships broadly indicate that mylonitic deformation, granite intrusion, and quartz veining all occurred at the same time.
Brittle fault movement on the western part of the Mogul fault occurred along a steep fault (~80°-85° S dip) that truncates the mylonitic fabric (~44° ± 9° S dip). As with the mylonitic shearing, fault movement was south-side-down as indicated by Tertiary conglomerate south of the fault that is juxtaposed with mylonitic rocks north of the fault. The ~35°-40° discordance between mylonitic foliation dip and the dip of the Mogul fault, and the discordance between the plunge of lineations associated with mylonitic and brittle deformations (east plunging vs. west plunging, respectively), suggest that the two periods of shearing were not closely related. However, in map view the mylonitic shear zone is parallel to the brittle fault. It thus seems likely that, although these two deformations were not simply products of shear zone movement during a period of decreasing temperature and rock plasticity, as is generally characteristic of metamorphic core complexes (e.g. Davis and Lister, 1988), they were broadly related to a period of normal shearing. Possibly incision of the footwall after mylonitization resulted in formation of a new fault that cut steeply across the mylonitic shear zone, and the incised fragment of the mylonitic footwall is concealed beneath the hanging wall (e.g. Lister and Davis, 1989).

Mylonitization accompanied emplacement of the alaskite, as shown by outcrops where mylonitization is better developed in Oracle Granite than in intruding alaskite. Copper mineralization and iron oxide staining, associated with the alaskite, also affect areas of brittle faulting, although it is unclear if this mineralization is entirely supergene.

**Little Hill mine.** The Little Hills mineral district encompasses several historic mines and many smaller prospects around the west end of the Mogul fault. Historic production (1937-1981) is recorded at 827,000 tons of ore yielding 5.7 million lbs. of copper, 53,000 lbs. of lead, 15,000 oz. of silver, and 300 oz. of gold (Keith et al., 1983). By far most of the copper, lead, and silver production (but none of the gold) came from the Little Hill mine, located within the Gold Hill claim (Durning, 1972), between 1960 and 1981. The Little Hill mine, with extensive underground workings, was located on the south flank of a small hill just east of the Silica Mines Inc. rock crushing facility and directly on the Mogul fault. The shaft is apparently now caved and buried, but in 2000 the 84° overhang of the hanging wall of the Mogul fault marked the approximate south side of the caved shaft. Ore was shipped to ASARCO for use as metal-bearing silica flux for ASARCO smelters (Durning, 1972).

Durning (1972, 1975) recognized a broad zone of alteration and mineralization north of the Mogul fault in the area of the Little Hill mine. Disseminated hydrothermal and secondary minerals in this zone include pyrite, chrysocolla, malachite, azurite, with secondary minerals common in fractures and along the Mogul fault. Quartz veins contain, in order of decreasing abundance, the following minerals (in addition to quartz and sericite): Pyrite, copper oxides (malachite, azurite, and chrysocolla), chalcopyrite, molybdenite, secondary chalcocite, secondary covellite, magnetite, hematite, and traces of galena and sphalerite (Durning, 1972). Quartz veins are generally approximately parallel to both the Mogul fault and the mylonitic foliation, as are abundant mineralized fractures. Quartz veins include banded quartz-rich and muscovitic vein material, with banding on scales of 1-20 cm. Veins are locally mylonitic, and have been affected by iron-oxide staining and local malachite on fracture surfaces. Irregular, dark red to black, iron-oxide clots possibly represent alteration of sulfides, but pseudomorphs were not seen.

**Cleavage.** A pervasive, weakly developed slatey cleavage is present in the pelitic rocks of the Apache Group and Lower Cambrian sedimentary rocks throughout much of an area where these rocks were mapped. The cleavage is also present in the Rice Peak porphyry, and is especially well-developed in the finer grained border zone of its intrusive contact in some areas. Mylonitic fabrics in the Rice Peak porphyry, including brittlely stretched plagioclase phenocrysts, are probably locally representative of this cleavage. The cleavage is oriented at a low angle to bedding on both sides of the Oro syncline and is consistently more gently dipping than bedding in the southwest limb and more steeply dipping than bedding in the northeast limb. This pattern strongly suggests that the cleavage is unrelated to the Oro syncline and was present in the rocks before folding. The fact that slatey cleavage is present in the Apache Peak area,
northeast of the Limb fault and the Oro syncline, also indicates that it is unrelated to the syncline. A weakly developed crenulation cleavage oriented parallel to the axial plane of the Oro syncline overprints the weak slaty cleavage and constitutes additional evidence that the slaty cleavage was present before folding. An equal area, lower hemisphere projection of poles to the pervasive weak cleavage, restored so that bedding is horizontal, shows that the cleavage was inclined to the west an average of about 25° throughout the study area before folding and formation of the Oro syncline (Figure 4). Cleavage and bedding intersect along roughly north-south trends that are at a high angle to the northwest strike of the axial plane of the Oro syncline, which further suggests that folding is unrelated to cleavage development. The cleavage is Laramide or younger because it cuts the Laramide Rice Peak porphyry, and it is older than the Oro syncline because it was folded by the syncline.

**Limb fault and Oro syncline.** The Limb fault extends northward from the southeastern corner of the map area to a point, about 400 m south of the Mogul fault, where it bends abruptly westward and strikes west-northwestward subparallel to the Mogul fault. The Limb fault dips steeply to the southwest. Stratigraphic throw indicates normal displacement. The Limb fault is paralleled by the Oro syncline (Figure 3; Plate 1; see also cross sections on Plate 1) which is located 120 to 360 m from the fault in its southeastern segment and about 1200 m from the fault along its northwestern segment. (The trace of the axial plane is not shown on Plate 1 for areas north of southeastern corner of the map because of potential confusion that might be introduced by adding another line to the map in an area already crowded with lines.) At the far southeastern corner of the map area, the Limb fault bends westward and truncates the Oro syncline (Suemnicht, 1977). Farther south, on the Mt. Lemmon 7½' Quadrangle, the Limb fault is truncated by the Catalina granite (Banks, 1976; Suemnicht 1977; Force, 1997). The Laramide Rice Peak porphyry forms a regional, sill-like sheet within the Pioneer Shale or at its base, and this geometry is characteristic of intrusions on both sides of Limb fault (Figure 3; Plate 1). This is almost certainly the result of intrusion of the Rice Peak porphyry into a largely undeformed, layered sequence that was later faulted by the Limb fault. The age of the Limb fault is thus constrained to be younger than the Laramide Rice Peak porphyry and older than final crystallization of the mid-Tertiary Catalina granite.

Parallelism between the Limb fault and Oro syncline, in all but the southernmost exposures, is suggestive of a genetic relationship between them. In addition, the margin of the Catalina granite, where it intrudes Pinal Schist and Oracle Granite, is broadly parallel to the Oro syncline and, to a lesser degree, the Limb fault. The origin of these geometrical relationships is not known, but one possibility that encompasses all three sub-parallel features is as follows: The Limb fault is related to intrusion of the Catalina granite, and formed so that it dipped inward toward the deep part of the pluton. Possibly, the Limb fault formed as part of a caldera-related ring-fracture system above a magma body now represented by the Catalina granite pluton, and the fault accommodated collapse of host rocks that were just within the ring-fracture system during caldera eruption and subsidence. The Oro syncline is possibly the product of movement on the Limb fault such that the hanging wall was displaced downward across a sigmoidal (in cross section) fault surface. In this scenario, the southwest limb of the fold was tilted to the northeast because it was displaced above the listric, deep part of the normal fault, and the northeast limb was tilted to the southwest because it was displaced above the anti-listric, shallow part of the normal fault. Faulting and folding ended by the time the Catalina granite crystallized. A similar Tertiary fold has been recognized, and a similar origin inferred, for the Spine syncline near Ray (e.g. Dickinson, 1995, p. 11-12). There is, however, no direct evidence that the Limb fault has such a sigmoidal fault form.

Another possibility is that the Oro syncline was produced by Laramide shortening, and later normal movement on the Limb fault and intrusion of the Catalina granite were localized by the fold. The layered, folded rocks of the syncline probably did not influence the intrusion of the granite, however, because the granite intrudes Pinal Schist and Oracle Granite that underlie the layered rocks and, at least at exposed structural levels, the Catalina granite is nowhere in contact with the layered rocks. Parallelism between the margin of the granite and the Oro syncline thus seems conspicuously coincidental in this case.
Figure 4. Schmidt equal-area net, lower hemisphere projection of poles to slatey cleavage after bedding has been restored to horizontal. Data collected from 59 cleavage - bedding pairs from pelitic rocks in the Apache Group and Lower Cambrian rocks in the Oro syncline and in the Apache Peak area, Oracle 7.5' Quadrangle, Pima and Pinal Counties, Arizona.
According to another possibility, the Limb fault formed as a steeply northeast-dipping Laramide reverse fault and the Oro syncline formed at the same time in response to the same deformation regime. Both were later tilted to the northeast in response to northeastward tilting of the entire Santa Catalina Mountains during mid-Tertiary exhumation (e.g., Spencer and Reynolds, 1989), and the reverse fault was tilted so that it appeared to have normal separation. This possibility also seems unlikely, however, because it also requires that the Oro syncline control the location of the intrusive margin of the Catalina granite. In summary, this issue is unresolved.

**Pirate Fault.** The western side of the Santa Catalina Mountains is a steep range front that forms the footwall to the west-dipping, west-side-down, Pirate fault. This inactive normal fault is exposed along the western foot of the range where it dips 50°-55° to the west and juxtaposes dominantly granitic rocks of the Santa Catalina Mountains with basin-filling, alluvial-fan sediments along the eastern side of Oro Valley (Dickinson, 1994). Analysis of gravity data indicates that down-dropped bedrock is at a depth of 2.0 ± 0.5 km beneath Oro Valley basin fill. The range front of the Santa Catalina Mountains rises to about 1.5 km above the basin filling sediments at the foot of the range. Total vertical displacement on the Pirate fault is therefore estimated at 3-4 km (Budden, 1975; Dickinson, 1994).

**Geomorphology of the Cañada del Oro.** Sediment accumulation in a large alluvial fan (map unit QTc) deposited by the ancestral Cañada del Oro buried the northern part of the Pirate fault. This alluvial fan contains diverse clast types derived from the northern Santa Catalina Mountains, and rests on granitic and metamorphic debris (map unit QTs) derived locally from the footwall of the Pirate fault (McFadden, 1981; Dickinson, 1994). The highest surface, known as the Cordones surface, forms the top of this relict alluvial fan. This fan surface extends westward from the northwest corner of the Santa Catalina Mountains, and is over 125 m above the modern Cañada del Oro stream bed at the eastern and highest part of the surface where Biosphere 2 is located. The Cordones surface is thought to be middle to early Pleistocene (McFadden, 1981). Quaternary down-cutting of basin-fill sediments by the Cañada del Oro has produced a series of benches along the west side of the Cañada del Oro where it flows southward adjacent to the Pirate fault.

Incision resulted in stranding of earlier erosion surfaces which now form a series of benches below the Cordones surface and above the modern Cañada del Oro (Figure 3; Plate 1). These benches typically include a veneer of stream gravels deposited before renewed incision, and benches with such sediments are known as "inset fill terraces." The alternating periods of stream aggradation and degradation that produced the sequence of inset fill terraces were interpreted by McFadden (1981) as the result of alternating Quaternary climatic conditions, although it has not been demonstrated that individual terraces can be correlated with individual Quaternary glacial or interglacial periods. Finally, terrace deposits may be thin in many areas because the surfaces received little new sediment before renewed incision. In this case, the surfaces are primarily strath terraces (W.R. Dickinson, oral communication, 2000).

Aerial photograph analysis reveals three well defined terraces west of the Cañada del Oro and south of the Cordones (southwestern corner of the map area). The lowest terrace is about 10-15 m above the modern Cañada del Oro, and the other two are at progressively higher relative elevations (Figure 5). Elevation differences between these terraces are typically 10-25 m (~30-80 feet). The terraces slope to the south parallel to the southward sloping floor of the modern Cañada del Oro (Figure 5). McFadden (1978) identified the same three terraces, but show them as more aerially extensive than is shown here on Plate 1. Apparently McFadden's criteria for terrace identification was based significantly on degree of soil development and soil characteristics, whereas terrace identification here is based only on the geomorphic criteria of a planar surface as identified in aerial photographs (USGS VFCH photo series).

The three terrace surfaces shown on Plate 1 and Figure 5 (Qh, Q11, and Qm) correspond to the Brave Bull, Catalina, and Twin Lakes surfaces of McFadden (1978, 1981). Comparison of terrace elevations with terraces on the adjacent Oracle Junction Quadrangle (Skotnicki, 2000) implies that the Q11 and Qm
Figure 5. Terrace elevations, Canada del Oro
surfaces identified here (Catalina and Twin Lakes surfaces, respectively) correlate with Skotnicki’s Qm2 and Qm1 surfaces, respectively. This correlation is consistent with McFadden’s terrace designations. (A single point on Figure 5, representing the northeasternmost and highest elevation point of Skotnicki’s Qm2 surface, lies above the Catalina surface (Q1,) as identified here, and is possibly a misidentified part of his Qm1 surface. Field checking will be necessary for clarification.)

The significance of these terraces is not known. Possibly each terrace corresponds to a particular glacial or interglacial climatic period in the late Pleistocene, and the three major terraces shown here correspond to the last three Pleistocene glacial/interglacial cycles. Resolution of this issue will probably require dating the surfaces, perhaps by using cosmogenic isotopes.

**Northern extent of the buried Pirate fault.** The inactive Pirate fault projects northward beneath the apex of the Cordones surface and approximately beneath Biosphere 2. Farther north it projects into the northwestern corner of exposed Oracle Granite that forms the north side of the Mogul fault, but was not identified in mapping of the granite. Most likely, the northward projection of the Pirate fault curves slightly to the west and remains concealed beneath Quaternary basin-filling sediments. An alternative, that the northern extension of the Pirate fault does not bend westward but is cut and offset to the west by left-lateral movement on the Mogul fault, is possible but considered highly unlikely because the Pirate fault, which has an enormous geomorphic signature, is almost certainly younger than the Mogul fault, which has almost no geomorphic expression. Also, striations on the Mogul fault suggest that the strike-slip component of the youngest and most brittle movement on the fault was right lateral rather than left lateral. It seems most likely, therefore, that the northward projection of the Mogul fault curves to the west and lies approximately beneath the point where State Highway 77 intersects the road to Biosphere 2. The Oracle Granite to the east of this area forms a pediment that gives no hint of a flanking, concealed fault, but such a fault should be recognizable with gravity surveys. Buried fault escarpments are potential sites for earth-fissure development in areas of groundwater withdrawal and water-table decline, and would thus be a potential geologic hazard if both housing development and groundwater pumping occur here on a large scale (Holzer, 1978).

**Proterozoic fossil (?)** A large boulder of medium-bedded quartzite, discovered in the Cañada del Oro below Biosphere 2, preserves a bedding surface with ring-shaped features that may be trace fossils (Figure 6). The boulder is thought to have been derived from one of two quartzite units in the lower Dripping Spring Quartzite. The ring-shaped features range in diameter from 7 to 12 cm and are preserved on a surface with a distinctive "elephant-skin" texture which may represent a fossilized algal-encrusted substrate. Such algal surfaces are commonly associated with Late Proterozoic multicellular trace fossils. The ring-shaped impressions are crudely similar to the latest Proterozoic Ediacaran fossils of Australia and similar fossils found in western North America. The apparent Middle Proterozoic age of these impressions is problematic for a multicellular trace fossil, however, because the Dripping Spring Quartzite is so old (it is intruded by 1100 Ma diabase). It is possible that the slab was derived from the Cambrian Bolsa Quartzite, but its lithology is not typical of this unit. The rings most likely represent colonial algae or reflect a chemical process involving reaction fronts migrating outward from a point. It is remotely possible that they are the fossils of a multicellular animal or represent the resting trace of a multicellular animal. The rock slab is available for inspection at the Arizona Geological Survey.
Figure 6. Ring features on slab of Dripping Spring Quartzite from Canada del Oro wash. (sample F0-318 from UTM zone 12, 3603540 N, 514360 E.)
CORRELATION OF MAP UNITS

Quaternary and late Tertiary map units

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Tertiary and Cretaceous map units

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Cambrian and Proterozoic map units

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pg. 13
Rock Units

Quaternary and Late Tertiary map units

Qyc  Young alluvium in active stream channels (Holocene, <0.5 ka)—Deposits of sand, silt, pebbles, cobbles, and boulders in the channels of ephemeral and perennial streams, typically coarse and poorly to very poorly sorted within mountain areas and on upper piedmonts. Particle size ranges from silt to cobbles or boulders. Deposits are typically composed of sand, silt, and pebbles on lower piedmonts, sand in major drainages, and sand, silt and mud in areas subject to overbank flooding. Within the larger channels distributary and anastomosing channel patterns are common. Most of the channel surfaces are modern in age, but vegetated bars may be several hundred years old.

Qy  Young alluvium (Holocene, <10 ka)—Sediments of this unit consist primarily of small active channels and low terraces along them in the montane and upper piedmont areas, and the vegetated and slightly elevated flanks of the active stream bed of the Cañada del Oro. Many small active channels are also included in unit Qy on piedmonts or in the mountains where they could not be differentiated from slightly older deposits at the map scale. In the mountains and on upper piedmonts particle sizes range from fine sand to boulders; on lower piedmonts sand, silt, and pebbles predominate. Qy deposits along the lower Cañada del Oro in the map area roughly correspond to the Golder terrace of McFadden (1978, 1981).

All areas mapped as Qy may be subject to inundation during large floods and should be considered as potentially flood prone unless geomorphologic or hydrologic/hydraulic analyses indicate they are not. Due to relatively high permeability and the variable potential for inundation, areas mapped as Qy have moderate to high potential for ground-water recharge.

Ql2  Terrace deposits (Late Pleistocene, 10 to 250 ka)—Late Pleistocene terrace deposits along the Cañada del Oro and south of the The Cordones. Terraces are underlain by a veneer of gravel deposited by the Cañada del Oro. Clast size is generally less than 30 cm. Clasts consist of diverse rock types typical of the modern Cañada del Oro. McFadden (1981) described these terraces as “inset fill terraces” that comprise a veneer of gravel deposited by the Cañada del Oro and conceal a substrate of light colored gravels of map unit QTs. Ql2 deposits correspond to the Brave Bull terrace deposits McFadden (1978, 1981) at the far southwest corner of the map area, and to map unit Q1 of Skotnicki (2000) in the adjacent Oracle Junction 7 ½’ Quadrangle.

Ql1  Terrace deposits (Late Pleistocene, 10 to 250 ka)—Late Pleistocene terrace deposits along the Cañada del Oro and south of the The Cordones. Terraces are underlain by a veneer of gravel deposited by the Cañada del Oro. Clast size is generally less than 30 cm. Clasts consist of diverse rock types typical of the modern Cañada del Oro. McFadden (1981) described these terraces as “inset fill terraces” that comprise a veneer of gravel deposited by the Cañada del Oro and conceal a substrate of light colored gravels of map unit QTs. Ql1 deposits underlie the Catalina terrace of McFadden (1978, 1981), and correlate with map unit Qm2 of Skotnicki (2000) in the adjacent Oracle Junction 7 ½’ Quadrangle.

Qm  Terrace deposits (Middle Pleistocene, 250 to 750 ka)—Late Pleistocene terrace deposits along the Cañada del Oro and south of the The Cordones. Terraces are underlain by a veneer of
gravel deposited by the Cañada del Oro. Clast size is generally less than 30 cm. Clasts consist of diverse rock types typical of the modern Cañada del Oro. McFadden (1981) described these terraces as “inset fill terraces” that comprise a veneer of gravel deposited by the Cañada del Oro and conceal a substrate of light colored gravels of map unit QTs. Although Qm deposits underlie areas mapped as Twin Lakes terrace by McFadden (1978, 1981), the Twin Lakes terrace is mapped McFadden over a much larger part of the map area than Qm deposits shown here. Areas mapped in this report as QTs and QTsc were included with the Twin Lakes terrace by McFadden (1978), and with map unit Qm1 of Skotnicki (2000) in the adjacent Oracle Junction 7 1/2’ Quadrangle.

In September of 2000 excavation had been completed, but houses not yet built, along the east side of Golf Course Drive at the eastern edge of section 26, in the community of Saddlebrook. Near the northeast corner of the section, excavation for homes and roads clearly revealed that the substrate consisted of granitic debris of the pre-Cordones gravels (map unit QTs), but farther south, on what is clearly the broad, flat part of the Qm terrace, at least 2 to 3 meters of lithologically diverse Cañada del Oro gravels formed the terrace surface, and granitic debris of map unit QTs was completely concealed.

**Qt**c Talus and colluvium (Quaternary)—Weakly to non-indurated gravel mantling hill slopes on bedrock. Consists of angular clasts of locally derived rock in a sand and clay matrix, derived by weathering of bedrock and downslope movement of regolith material. Mapped where hill slope deposits are thick enough to obscure the nature of the underlying bedrock. Nonconformably overlies all older deposits.

**Qs** Surficial deposits, undivided (Quaternary)—Undivided alluvium, talus, colluvium, and local active channel deposits. Typically consists of weakly to moderately indurated gravel and sand with substantial soil development in some areas. Primarily exposed on hill slopes and flanking washes and stream beds adjacent to hills and mountains. Also includes alluvium in recently active channels and some colluvium and talus.

**Qls** Landslide deposits (Quaternary)—Poorly consolidated to unconsolidated, very poorly sorted mud to large boulders (up to 10 m).

**QTC** Cordones Fanglomerate (Pleistocene to Pliocene)—Fanglomerate containing generally subrounded, typically 3-30 cm clasts of Pinal Schist, the Proterozoic Apache Group and intruding diabase, Rice Peak porphyry, and granitoids. The fanglomerate is poorly sorted and consolidated, and is deeply weathered on the Cordones surface (McFadden, 1981). It rests largely on granitic debris derived from the west face of the Santa Catalina Mountains and overlaps the Pirate Fault (Dickinson, 1994).

This fanglomerate was derived from the ancestral Cañada del Oro headwaters and was deposited in an alluvial fan with an apex in the area where the modern Cañada del Oro exits the Santa Catalina Mountains. The top of this alluvial fan, named the Cordones surface (McFadden, 1981), is now far above the Cañada del Oro river bed due to Quaternary incision by the river. The southeastern edge of this surface, a 10 km long escarpment that extends from Catalina northeastward to Biosphere 2, and the linear ridges behind it, are named “The Cordones” on the U.S. Geological Survey 7 1/2’ Quadrangles (Oracle, 1988, and Oracle Junction, 1988). The Cordones Fanglomerate is named for exposures of this unit in the southeast facing escarpment at the edge of the Cordones surface. It rests on Pre-Cordones gravels west of the Pirate fault and on bedrock east of the fault.
**QTs** Pre-Cordones gravels (Pleistocene to Pliocene)—Non-indurated to weakly indurated, cobble to boulder conglomerate and gravel. In the southwestern part of the map area, west of the Pirate fault and south of the Cordones, this unit consists largely of poorly sorted, light colored, disaggregated granite that was derived locally from the Catalina granite (map unit Tg) that forms the uplifted footwall of the adjacent Pirate fault. Locally, where this unit is juxtaposed across the Pirate Fault with Pinal Schist, it consists exclusively of Pinal Schist debris (Dickinson, 1994). Grain size increases from gravel and grus in the west to boulder conglomerate adjacent to the Pirate Fault. This unit is interpreted as having been deposited by alluvial fans and talus cones derived locally from the uplifted footwall of the Pirate fault (Dickinson, 1994).

**QTsc** Pre-Cordones gravels and mantling terrace deposits and locally derived sediments, undivided (Pleistocene to Pliocene)—Pre-Cordones gravels that have been variably concealed by terrace deposits and by reworked terrace deposits and Cordones fanglomerate. Pre-Cordones gravels (map unit QTs) are visible in aerial photographs (USGS VFCH photoset, 1982) because of their light color, but in many areas pre-Cordones gravels are variably concealed by a complex combination of dissected terrace deposits, reworked terrace deposits, and colluvium and thin alluvial deposits derived from Cordones fanglomerate. This map unit (QTsc) is applied to areas that are primarily dark on the aerial photographs but that contain local areas of light colors thought to be pre-Cordones gravels. Areas included in this map unit are not obviously part of a terrace.

**Tertiary and Cretaceous map units**

**Tc** Conglomerate (Pliocene or Miocene)—Massive to crudely stratified, cobble to boulder conglomerate. Clasts are mostly 3-30 cm and are locally as large as 2 m. Many smaller clasts are subangular, others are subrounded. Clasts include Sierra Ancha diabase, Mescal Limestone, Dripping Spring Quartzite, Rice Peak porphyry, black siliceous hornfels, and fine grained, equigranular leucogranite. The absence of Pinal Schist and Oracle Granite from the clast suite is striking, given that the Pinal Schist forms the depositional base of some of the conglomerate, and that the Oracle Granite is exposed over a very large area on the north side of the Oracle Fault. The absence of Oracle Granite suggests that the conglomerate was deposited before the north side of the Mogul fault had been uplifted by movement on the Mogul Fault.

A pre-Quaternary age for this unit is inferred because the unit is cut by the Mogul fault, which is overlain by unfaulted Quaternary fan sediments and has no geomorphic signature where it projects westward beneath the Cordones surface. A middle to late Tertiary age is inferred because the conglomerate is only weakly cemented and lithified, color is only weakly modified from inferred original pale gray to present pale brown and tan.

**Ta** Little Hill alaskite (Tertiary)—Medium to fine-grained, variably muscovitic leucogranite intruded into Oracle Granite in the Little Hill mine area. Named by Durning (1972). Lower case "a" in "alaskite," following Durning (1972), is intended to maintain informal nature of term, as type locality has not been designated. Age is based on inference that mylonitization is associated with the alaskite and with the Mogul fault, and the Mogul fault cuts conglomerate of inferred Oligo-Miocene age. Alaskite, mylonitization, and fault movement are all thought to be Oligo-Miocene in age.

Mylonitic fabric is well developed in this rock unit and in adjacent host Oracle Granite where the two are interleaved by intrusion of sheet-like leucogranite dikes into Oracle Granite and
shearing parallel to sheet margins. Locally abundant quartz veins, 5-20 cm thick, parallel mylonitic foliation. Leucogranite and locally associated quartz veins and host granite are moderately lineated. Mylonitic fabric dies out over several tens of meters into host Oracle Granite. In some areas injection of leucogranite outlasted mylonitization, and non-mylonitic leucogranite sills inject mylonitic Oracle Granite.

Tf Felsite dike (Tertiary?)—Very fine grained to aphanitic dikes with a pale gray groundmass with >1 mm disseminated opaques, sparse disseminated pyrite, and <1% 1-2 mm feldspar phenocrysts. These dikes are suspected to be related to the Little Hill alaskite (map unit Ta).

Tap Aplitic to pegmatitic dike (Tertiary?)—Fine grained muscovite aplite to coarse grained quartz-feldspar pegmatite. These dikes are suspected to be related to the Little Hill alaskite (map unit Ta).

Tg Catalina granite (Tertiary)—Porphyritic biotite ± hornblende granite. Pink orthoclase phenocrysts are as long as 4 cm (Suemnicht, 1977) to perhaps 7 cm (Budden, 1975). Xenoliths are locally abundant (Budden, 1975). Texture is hypidiomorphic granular and plagioclase composition is An 26-32 (Suemnicht, 1977).

Many different names have been used for this granitoid intrusion, but the most common has been Catalina granite (Bromfield, 1952; McCullough, 1963; Shakel et al., 1972, 1977; Budden, 1975; Suemnicht, 1977; Reynolds et al., 1986). Creasey et al. (1977) referred to this intrusion, and much of the rest of the granitoids and gneissic granitoids in the Santa Catalina Mountains, as “quartz monzonite of Samaniego Ridge.” However, 11 of 13 modal mineral determinations indicate that the unit is a granite according to the IUGS classification of 1973 (Table 1). Because of conflicting name usage and because a type area has not been designated, the term “Catalina granite” is here considered informal.

Three K-Ar dates considered reliable by Reynolds et al. (1986) range from 24.0 Ma to 25.6 Ma (Damon and others, 1963; Creasey and others, 1977). whole rock Rb-Sr isotopic analyses indicate an age of ~26 Ma (Keith et al., 1980), and Shakel et al. (1977) report “nearly concordant 27 ± 2 m.y. old zircons,” but give no analytical data or location information.

Catalina granite, aplitic (Tertiary)—Identified and mapped by Erickson (1962), and described as equigranular aplite that is locally coarse grained and possibly pegmatitic along the margin of the Catalina granite.

TKr Rice Peak porphyry (Early Tertiary to Late Cretaceous)—Medium gray to greenish gray, poorly resistant hypabyssal intrusions containing up to 30% chalky, white, relict plagioclase 2-8 mm diameter and sparse, 1-3 mm biotite, in a microcrystalline groundmass. K-Feldspar phenocrysts up to 2 cm long and comprising up to 4% of the dike rock were identified south of Irene Wash in NW ¼, sec. 15, T. 10 S., R. 15 E. Quartz-phryic phases of the porphyry form small bodies near the margins of the large intrusive bodies. Suemnicht (1977) also recognized quartz phenocrysts. Commonly forms sills and dikes in the Apache Group. Strong foliation, including brittlely stretched plagioclase phenocrysts, and weak slatey cleavage development, is characteristic of some areas, especially near the margins of large sheet-like intrusions.

This name “Rice Peak porphyry” is considered informal. Creasey (1967) used the name “granodiorite porphyry” and Keith et al. (1980) used the name “Rice Peak granodiorite porphyry,” but the rock rarely contains quartz or K-feldspar in most exposures and so is not a granodiorite according to the IUGS classification (Streckeisen, 1973). A U-Pb date of 70.6 ± 7.6 Ma was obtained from zircon crystals from a sample of this rock (Unruh, 1997).
Table 1. Catalina Granite Modal Mineralogy

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<th>Quartz</th>
<th>Plag.</th>
<th>K-feld.</th>
<th>Bio.</th>
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<th>Total</th>
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Erickson, 1961, as interpreted by Hoelle, 1976

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<th>Sample</th>
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<th>K-feld.</th>
<th>Bio.</th>
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Note: if % P/P+K is 10 to 65, and % Q/P+K+Q is 20 to 60, then rock is a granite according to IUGS (Streckeisen, 1973)
Cambrian and Proterozoic map units

The Cambrian Bolsa Quartzite and Abrigo Shale of southeastern Arizona are represented in the Oracle Quadrangle by an ~200-m-thick sequence of alternating quartzite, dolostone, and weakly metamorphosed, thin-bedded, argillaceous mudstone, siltstone, and fine-grained sandstone. In the southernmost exposures in the map area, Cambrian strata consist of a lower, massive, thick-bedded quartzite (Bolsa Quartzite) overlain by thin-bedded argillite and metasandstone with abundant trace fossils (Abrigo Shale). However, in northern exposures, lithologies are mixed and correlation with Bolsa Quartzite and Abrigo Shale is problematic. Because of difficulties in correlating map units with the Bolsa Quartzite and Abrigo Shale, in this report these units are simply divided into quartzite (Cq), fine-grained clastic metasedimentary rocks (Cs), and carbonate (Cc).

In the SE ¼, sec. 15, T. 10 S., R. 15 E., Cambrian strata are dominated by the following lithologies, in ascending order: (1) basal quartzite, (2) metasiltstone and fine-grained metasandstone, (3) dolostone, (4) metasandstone and quartzite, and (5) dolostone. The basal quartzite pinches out westward, and in the western half of section 15, metasiltstone and fine-grained metasandstone rest directly on Proterozoic diabase, and a quartzite lens is present within the fine-grained metasandstone of unit (2). A stratigraphic section through most the upper part of the second of these five units, and overlying units 3, 4, and 5, is described in Appendix A (Figure A1).

Cq Quartzite (Cambrian)—Fine- to coarse-grained, thin- to thick-bedded, resistant quartzite (>95% quartz) and feldspathic quartzite. Includes coarse, vitreous, light gray to whitish gray, cross-bedded quartzite. Grains locally up to 3-4 mm. Dark laminations rich in magnetite reveal cross bedding and are characteristic regionally of Cambrian Bolsa Quartzite in areas where Proterozoic diabase was exposed during initial Cambrian sedimentation. Commonly blocky weathering.

At the center of section 15, T. 10 S., R. 15 E., quartzite is well exposed in a trench and consists of medium- to thick-bedded, medium-grained quartzite to feldspathic quartzite with iron-oxide stained pits where feldspar or opaque minerals were destroyed by alteration. Cross bedding is clearly revealed by recess-forming, rust-stained laminations that contain a higher abundance of iron-oxide stained pits than adjacent rock. Tabular-planar cross bedding (McKee and Weir, 1953) characterizes quartzite beds up to 40 cm thick. Also, herringbone cross beds are locally present. Some beds pinch and swell in a manner suggestive of channels. At this locality, quartzite grades up section over 1 meter into thinly bedded to very fine grained quartzite and very fine grained metasandstone with abundant silty laminations that form parting surfaces. At one locality along the Cañada del Oro stream bed (UTM 3601280N, 519625E), medium-bedded sandstone contains Skolithus burrows up to 20 cm long.

Cc Carbonate (Cambrian)—Massive to weakly bedded, medium-gray dolostone, locally with protruding 1-2 cm knots and irregular blobs of chert and siliceous rock. Four samples tested for reactivity with HCl were all found to be dolostone.

Cs Metasiltstone (Cambrian)—Mostly greenish brown, brown, and black, variably argillaceous metasiltstone and very fine grained to fine-grained, thinly bedded to laminated metasandstone. Thin beds are locally lensoidal and suggestive of ripples. Shaley character and greenish colors seem dominant at the base. Also includes carbonate, silty and sandy carbonate, calcareous sandstone, and argillite.

On the slope above and to the southeast of a dirt road, ~100 m south of the center of sec. 15, T. 10 S., R. 15 E., a sequence of argillaceous, silty, and calcareous rocks is fairly well exposed between two mapped sheets of Cambrian quartzite. The sequence is as follows, from base to
top: (1) platy, variably calcareous argillite and metasiltstone with trace fossil grooves (see below) overlain by rubble of platy silty carbonate and argillaceous metasiltstone, (2) fine- to medium-grained metasandstone and calcareous metasandstone. Total thickness of (1) and (2) is ~20-30 m. (3) Rubble and sparse outcrop of silty and sandy carbonate that is gray and tan, and thin to medium bedded, with less abundant metasiltstone and sandy metasiltstone. Thickness ~5 m. (4) Massive to blocky, medium-gray to tannish-gray carbonate with sparse 1-2 cm knots of silica and coarse calcite. Thickness 5-8 m. (5) Platy, silty, tan to orangish-tan carbonate. Thickness ~12 m.

Numerous grooves and furrows locally within argillaceous metasiltstone are 1-7 mm across and up to 8 cm long, with irregular and non-parallel trends. These are especially abundant within a few meters of underlying quartzite or diabase. These trace fossils indicate that this argillaceous metasiltstone is not correlative with argillite in the Proterozoic Mescal Limestone, but rather is Phanerozoic in age. Furthermore, trace fossils are present within 5 cm of underlying diabase, indicating that diabase formed the surface upon which basal Cambrian silts were deposited. No contact metamorphism was recognized at the contact where metasiltstone rests on diabase.

**Campo Bonito Formation (Middle Proterozoic to Cambrian)**—Black mudstone, argillaceous, micaceous sandstone, pebbly sandstone, and cobble conglomerate containing sub-angular to sub-rounded, typically non-spherical pebbles of chert (see Appendix A, Figure A2). This unit, named by Force (1997), ranges from 0 to 30 meters thick and rests unconformably on Mescal Limestone or Dripping Spring Quartzite. Medium- to thin-bedded, chert-pebble conglomerate is most abundant toward the base. The conglomerate has a black argillaceous sandy matrix, but the pebbles are arranged in thin layers with intervening argillaceous granule sandstone. No evidence of the massive, unsorted diamictite facies described by Force (1997) was observed in the map area. Higher in the section pebbles are concentrated in medium- to thin-bedded units or as pebble trains within laminated and low-angle cross-bedded argillaceous sandstone. The upper part of the unit consists of monotonous, black, sandy argillite with rare granule or pebble trains. The argillaceous matrix is iron-rich, hematitic, and very fine specular hematite possibly accounts for the black, shiny appearance of the unit. Similar pebbly mudstones are present within the Mescal Limestone and possibly along the contact between the Apache Group and the base of the Cambrian in areas where the Mescal Limestone is not present. These pebbly mudstones can be distinguished from the Campo Bonito Formation because they typically contain more dolostone pebbles than chert, the argillaceous component is green instead of black and some are intruded by diabase. The possible age range of the Campo Bonito Formation is Middle Proterozoic to Cambrian. The lack of fossils might be because it is a terrestrial unit, and the fact that no diabase is known to intrude the unit separates it from the Apache Group.

**Sierra Ancha Diabase (Middle Proterozoic)**—Dark-gray, dark greenish gray, and grayish black sills and dikes with typical sub-ophitic, diabasic texture (Wrucke, 1989).

**Apache Group (Middle Proterozoic)**

**Mescal Limestone, Apache Group (Middle Proterozoic)**—Laminated to thin-bedded, light- to medium-gray to tannish-gray carbonate (see Appendix A, Figure A3). Unit contains medium-gray, 1- to 30-cm-thick chert beds and siliceous thin beds, laminations, stringers, lenses, and blobs that form protruding, tan to brown ribs between recess-forming carbonate layers. Locally, rocks of this unit part along silty layers to form slabs. One sample of this unit was
determined, using 10% HCl to test for reactivity, to be limestone (10-19-99-3), whereas another was dolostone (10-21-99-2). The limestone sample was collected on a small ridge crest south of Irene Wash along the west edge of the NW ¼, sec. 15, T. 10 S., R. 15 E., at a plotted bedding-attitude symbol with a 15° dip (Plate 1).

Yma Mescal Limestone, argillite unit, Apache Group (Middle Proterozoic)—

Yds Dripping Spring Quartzite, undivided, Apache Group (Middle Proterozoic)—Thin- to medium-bedded, fine- to medium-grained quartzite, locally with silty laminations and partings (see Appendix A, Figure A4). Locally pale gray and thick bedded to massive. Formal unit defined by Ransome (1919).

East of lower Dodge Wash the Dripping Spring Quartzite is directly overlain by Cambrian quartzite where the Mescal Limestone was removed by erosion before deposition of Cambrian strata. The blocky, resistant Cambrian quartzite overlies orangish brown, silty, fine-grained sandstone and sandy siltstone that weathers into slabs and small fragments.

In the NE ¼, sec. 15, T. 10 S., R. 15 E., southeast of the point where Irene Wash crosses the Limb fault, the top of the Dripping Spring Quartzite consist of a 1- to 3-m-thick zone of medium- to thick-bedded, white, medium-grained, clean quartzite, overlain by a 3- to 5-m-thick zone of metasandstone that is progressively more poorly sorted, darker, and more impure up section and is directly overlain by thin-bedded to laminated metasiltstone and silty carbonate of the Mescal Limestone. The contact between the Dripping Spring Quartzite and the Mescal Limestone is placed at the top of the metasiltstone and below the lowest silty carbonate, although typically the metasiltstone is covered and the contact is placed in the covered interval above the resistant quartzite marker unit of the uppermost Dripping Spring Quartzite and below the lowest carbonate beds of the Mescal Limestone.

A 10-cm-thick sequence of white, laminated rock, interbedded with medium-bedded sandstones in the middle part (about 100 meters above the "Second Quartzite" of Figure A4) of the Dripping Spring Quartzite, may be an ash layer. A hand specimen showing the entire bed with the upper and lower divisions labeled was collected as FO-112. The bed was sampled in two parts for U-Pb geochronology. The upper 2 cm of the bed is very fine-grained and massive (FO-112-u). The main body of the 10 cm layer was sampled as FO-112-l. Sample location is 3603275N, 516675E (UTM grid zone 12). The samples were sent to Sam Bowring, Massachusetts Institute of Technology on December 20, 1999 for U-Pb zircon geochronologic analysis.

In the NW ¼, sec. 15, T. 10 S., R. 15 E., in the bottom of Irene Wash, rocks of this unit are highly fractured, injected with quartz veins, altered so that quartz is sutured, and pervasively stained with red iron oxides, especially in area of adits and prospects.

Ydsq Dripping Spring Quartzite, prominent quartzite unit, Apache Group (Middle Proterozoic)

Ydsb Barnes Conglomerate member, Dripping Spring Quartzite, Apache Group (Middle Proterozoic)—This basal member of the Dripping Spring Quartzite consists of up to 10 m of distinctive clast-supported pebble to cobble conglomerate. Clasts are subrounded to well rounded, and include conspicuous white vein quartz, red jasper, and less conspicuous quartzite, all up to 20 cm diameter. This unit is shown on Plate 1 as a string of dots where it was identified but is too thin to outline as a map unit.

Yp Pioneer Formation, Apache Group (Middle Proterozoic)—Commonly massive, typically gray to lavender argillite and metasiltstone with 10% thin- to medium-bedded, very fine grained
metasandstone. Incipient cleavage is associated with phyllosilicate content. Formal unit defined by Ransome (1919).

A 2- to 5-cm-thick layer of laminated, soft, white mud or ash-stone that occurs at the contact between the Scanlon Conglomerate and Pioneer Formation was sampled for U-Pb geochronologic analysis. The ash or mudstone was sampled as FO-317 and it directly overlies pebbly arkose of the Scanlon Conglomerate which is too thin at this locality to be shown on the map. Location of the sample is 3603525N, 51375E (UTM grid zone 12). The sample was sent to Sam Bowring, Massachusetts Institute of Technology on December 20, 1999.

Yps Scanlon Conglomerate member of the Pioneer Shale, Apache Group (Middle Proterozoic)—A thin (0-5 meters) conglomerate containing angular to subrounded pebbles and cobbles, and quartzose sandstone. Clasts are dominantly bull quartz, metamorphic rock fragments derived from the underlying Pinal Schist, and granitic rock fragments derived from the Oracle Granite. The sandstones are typically medium- to thin-bedded, laminated to cross-bedded quartzite or feldspathic quartzite. They are virtually indistinguishable from sandstones in the Pioneer Shale and Dripping Spring Quartzite. In most areas, the unit is so thin as to be unmappable at 1:24,000 scale. Along the steep eastern canyon wall of the Cañada del Oro, a thin veneer of Scanlon Conglomerate is commonly preserved along the base of flat-bottomed intrusive bodies of the Rice Peak porphyry.

(base of the Apache Group)

Yo Oracle Granite (Middle Proterozoic)—Coarse-grained, porphyritic, biotite granite named the Oracle Granite by Peterson (1938). Renamed quartz monzonite by Creasey (1967), but 4 modal mineral determinations by Creasey (1967) indicate that the unit is a granite according to the IUGS granite classification (Streckeisen, 1973). Six radiometric age determinations considered likely to represent the approximate age of the granite by Reynolds et al. (1986) range from 1380 to 1430 Ma.

Yoc Oracle Granite, cataclastically deformed (Middle Proterozoic protolith, Tertiary(?)
defformation)—Gray, very fine grained, quartz-feldspar-chlorite(? groundmass with quartz and feldspar clasts up to 2 cm diameter. Color bands 3-5 mm thick are aligned with long axes of clasts. Rock is strongly indurated and includes black pseudotachylite(? veins, up to 7 mm thick, with variable orientation. This rock unit is located adjacent to the Mogul fault at the eastern edge of the map area.

Yom Oracle Granite, mylonitically deformed (Middle Proterozoic protolith, Tertiary(?)
defformation)—Oracle Granite that is mylonitized. Generally, mylonitic Oracle Granite is injected with sheets of leucogranite of the Little Hill alaskite and quartz veins. Iron oxides and, locally, secondary copper minerals are associated with alteration within several tens of meters of the quartz veins and leucogranite intrusions in Oracle Granite.

YoA Aplite and pegmatite associated with the Oracle Granite (Middle Proterozoic)—Dike located near northeast corner of quadrangle, identified by Force (1997) and thought by him to be related to the Oracle Granite.

Xp Pinal Schist (Middle Proterozoic)—Pale-gray to medium-gray schist and psammitic schist that is sufficiently metamorphosed that pelitic rocks have significant phyllosilicate development and cleavage parallel to preferred orientation of phyllosilicates. Phyllosilicates, locally visible in hand sample without the aid of a hand lens, impart a silvery sheen to the rock. Also, quartz
veins and stringers are locally abundant, especially in pelitic rocks. Locally includes fine- to medium-grained, felsic granitoid dikes.

References Cited


Appendix A: Measured stratigraphic sections

Figure A1. Stratigraphic section of basal Cambrian strata measured on steep slopes of Dodge Wash, SE ¼, SE ¼, sec. 15 (lower three units), and from steep slopes just north of the center of the southern edge of section 15 (overlying units). Section measured by J.E. Spencer, December 2, 1999.

Figure A2. Stratigraphic section of the Campo Bonito Formation measured near the mouth of a tributary to the upper Canada del Oro. UTM (grid zone 12) coordinates, base of the section: 3600035N, 520550E, top of the section: 3600120N, 520580E. Section measured by C.A. Ferguson, December 3, 1999. Complete sample numbers include the prefix FO-.

Figure A3. Stratigraphic section of the Mescal Limestone including the base of the overlying Campo Bonito Formation and the upper part of the underlying Dripping Spring Quartzite. Section starts in upper Canada del Oro at the base of an overhanging stream cut. UTM (grid zone 12) coordinates, base of section: 3599870N, 520280E, top of section: 3599790N, 520430E. Section measured by C.A. Ferguson, December 3, 1999. Complete sample numbers include the prefix FO-.

Figure A4. Stratigraphic section of the Apache Group measured on the northern canyon wall of the Canada del Oro just east of Biosphere II. UTM (grid zone 12) coordinates, base of the section: 3603800N, 514900E, top of the section: 3604380N, 515200E. Section measured by C.A. Ferguson, March 30, 2000.
EXPLANATION

12m: Massive brownish gray dolostone

1m: White, fine grained quartzite

4m: Covered interval

15m: Thin to thick bedded, fine grained, plane bedded psammit with numerous iron-oxide-stained pits replacing unidentified feldspar or lithic fragments. Grades up section into quartzite.

4m: Covered interval

9m: Moderately to poorly resistant, orangish tan weathering dolostone, thin to thick bedded, dark gray on fresh surfaces.

5m: Thick bedded, tan (on fresh and weathered surfaces) dolostone without chert nodules, blocky weathering. Locally thin bedded with platy weathering.

4m: Massive medium gray dolostone with light, 2-8 cm diameter, irregular chert nodules.

3m: Grayish white, resistant quartzite, thin bedding faintly visible, locally cross bedded within 5-10-cm-thick beds, weathers into blocks.

10m: Recessive, dark gray, thin to medium bedded psammit and semipelite, locally cross bedded. Includes well-developed trace fossils. Includes minor pelite.

7m: Resistant, tan to brown, platy, 1-10-cm-thick beds of calcareous psammit. This psammit rests on dark greenish gray, poorly sorted psammit that forms the top of the underlying quartzite unit that represents the basal unit of the Cambrian sequence.

Figure A1
26) covered, top of section is faulted against Cambrian Abrigo Formation
25) 21m: thin-bedded to laminated, black, silty mudstone with abundant detrital mica, and rare thin-bedded granule sandstone or argillaceous sandstone beds
24) 4m: massive, internally laminated and low-angle cross-stratified, pebbly, silty mudstone
23) 150cm: laminated to plane-bedded, silty mudstone with little or no pebble trains
22) 25cm: sparsely pebble- and granule-bearing, laminated, silty mudstone
21) 40cm: laminated silty mudstone with sparse granules and pebbles throughout and a 10cm-thick concentrated zone of matrix-supported conglomerate at the top
20) 150cm: pebble, rarely cobbly, elongate subangular-to subrounded-clast, clast-supported conglomerate with silty, black, argillaceous matrix. Clasts consist of massive white to purple mottled chert, laminated grayish brown chert, and grayish brown massive chert.
19) 110cm: laminated, black argillaceous sandstone with scattered, discontinuous pebble trains
18) 30cm: pebbly, rarely cobbly, chert-clast conglomerate
17) 160cm: laminated to thin-bedded chert and pyritic mudstone with a gossaned chert breccia base and some gossaned, thin mudstone intervals
16) 55cm: medium- to thin-bedded, massive, light brown weathering chert with thin laminated and very thin laminated silty interbeds
15) 10cm: gossan alteration zone
14) 20cm: massive chert
13) 30cm: laminated chert
12) 40cm: gossan altered chert
11) 100cm: covered
10) 88cm: upward thickening algal laminated, to thin-bedded, white dolostone (gradational lower contact)
9) 35cm: light brown, algal laminated dolostone (sharp lower contact)
8) 45cm: dark green (chloritic?), laminated, silty mudstone with elongate cobble-pebble clasts of light brown dolostone near base (sharp lower contact)
7) 50cm: thin-bedded to laminated cream-colored dolostone (diffuse lower contact)
6) 200cm: green, laminated, silty mudstone
5) 30cm: chert clast breccia
4) 160cm: light green, laminated mudstone with laminated to very thin-bedded dolostone near base (sharp lower contact)
3) 100cm: light green, laminated mudstone
2) 80cm: laminated to very thin-bedded dolostone interbedded with green mudstone and chert
1) 160cm: laminated green silty mudstone

Figure A2
Call1Po Bonito
formation

black mudstone
500cm: covered

63cm: algal laminated dolostone
10cm: chert
190cm: algal laminated dolostone
20cm: laminated white chert
216cm: algal laminated dolostone

373cm: diabase

236cm: algal laminated, buff-colored dolostone

246cm: rubbly outcrop of light-colored, algal laminated limestone (gradational lower contact)

380cm: diabase?

75cm: laminated to thin-bedded chert and dolostone?

180cm: covered

228cm: wavy laminated, massive, green chert (gradational lower contact)

152cm: massive, green, chert-pebble conglomerate and/or in situ karstic breccia (sharp lower contact)

152cm: medium-bedded, massive, vuggy weathering, greenish gray argillaceous granule to coarse-grained sandstone (sample 266), with interbeds of internally laminated, thin- to medium-bedded, cherty mudstone (sharp lower contact)

250cm: medium- to thin-bedded, plane-bedded, fine- to medium-grained, quartzose sandstone with granule to coarse sandstone beds near top

776cm: medium- to coarse-grained, medium- to thick-bedded, plane-bedded to massive, feldspathic sandstone (gradational lower contact)

990cm: 6:1 sandstone:mudstone consisting of medium- to thick-bedded, black, massive to plane-bedded, argillaceous sandstone with thin-bedded to laminated, silty, black mudstone interbeds (sharp lower contact)

1000cm: 5:1 mudstone:sandstone with massive, medium-bedded, argillaceous sandstone interbedded with thin-bedded to laminated and ripple-laminated, swaley to plane-bedded, silty, sandy, pyritic, black mudstone.

Figure A3
**EXPLANATION**

- Carbonate
- Argillaceous sandstone and mudstone
- Sandstone
- Mudstone
- Conglomerate
- Tuff?
- Diabase

**Generalized stratigraphic section, northwestern Santa Catalina Mts**

- Cambrian
- Late Ordovician
- Middle Ordovician
- Proterozoic
- Early Proterozoic

- Cordones Gravel
- Olive green siltstone and medium- to thin-beded, argillaceous sandstone with granule trains
- Massive, feldspathic quartzite
- Laminated to thin-beded, reddish brown to light gray, pyritic mudstone and siltstone
- Feldspathic quartzite
- Massive quartzite with abundant bed-parallel styolites
- Greenish-gray, medium- to thin-beded, rarely thick-beded argillaceous sandstone interbedded with siltstone and mudstone
- "Second Quartzite": >75% medium- to thick-beded, plane-beded to cross-stratified, light gray to pale green quartzite with 2-5 cm spherical siliceous concretions. Bedding surfaces characterized by elephant skin texture
- Dark gray to purple, laminated to thin-beded, silty mudstone
- "Lower Quartzite": ~60% medium- to thick-beded, plane-beded to cross-stratified quartzite with 1-2 cm concretions and dark green interbeds of argillaceous siltstone and mudstone
- Barnes Conglomerate member of the Dripping Spring Quartzite: medium- to thick-beded, well-rounded, cobble-boulder conglomerate and sandstone
- Pioneer Shale: laminated, silty, dark gray mudstone with <10% thin- and medium-beded sandstone interbeds
- Diabase (other sills occur throughout the section)
- Scanlan Conglomerate member of the Pioneer Shale
- Pinal Schist

**Figure A4**