GEOLOGIC FRAMEWORK OF THE CATALINA FOOTHILLS, OUTSKIRTS OF TUCSON (PIMA COUNTY, ARIZONA)

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ARIZONA GEOLOGICAL SURVEY CONTRIBUTED MAP CM-99-B (31 pp., 1 Plate)

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[Text and Legend to Accompany 1:24,000 Map]

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Introduction and Purpose

Past geologic maps and accounts of the sedimentary, geomorphic, and structural geology of the piedmont of the Santa Catalina Mountains in the outskirts of Tucson by Voelger (1953), Pashley (1966), Davidson (1973), Creasey and Theodore (1975), Banks (1976), Anderson (1987), Pearthree et al. (1988), McKittrick (1988), and Jackson (1989) raised questions about the sedimentary evolution of the foothills belt that were left open or unresolved. Multiple dissected alluvial fans and pediments overlie much older faulted and tilted strata to form Cenozoic sedimentary assemblages of considerable stratigraphic and structural complexity. As a contribution to improved understanding of urban geology in the Tucson metropolitan area, systematic geologic mapping of the piedmont belt was undertaken to establish the overall geologic framework of the Catalina foothills (~175 km^2) at a common scale (1:24,000). The area studied extends from Oracle Road on the west to the vicinity of Rinconado Road on the east, and from the Rillito River and Tanque Verde Wash northward to the limit of bedrock exposures at the base of the Santa Catalina Mountains.

A dense network of suburban roads allows detailed access to nearly all parts of the Catalina foothills, although multiple gated communities and undeveloped tracts closed to public entry prevent ready access to selected parts of the mapped area. Roadcuts provide the most informative outcrops of most sedimentary units, and many of them did not exist during previous studies. Comparable natural outcrops are limited to fortuitous stream cutbanks and especially steep ravine slopes unmantled by soil cover. Aerial photographs were invaluable accessories to the field work, allowing the continuity of sedimentary entities, or discontinuities between them, to be traced through areas of poor exposure. The irregular distribution of bedding attitudes on the accompanying geologic map is for the most part not reflective of variable intensity of field investigation, but of variable occurrence of adequate exposures. Most outcrops allowing strikes and dips of bedding to be measured with confidence were probably visited during the course of the field work. For clarity of graphic display, all mapped contacts between different sedimentary units on the accompanying geologic map are shown as solid lines, even though normal mapping convention would require long segments of most contacts to be dashed to indicate only approximate location. Exclusive use of solid contact lines should not be interpreted as reflecting fully accurate placement of all contacts.

No attempt was made during the field work to delineate the extent of washfloor alluvium along minor tributary drainages, nor of patches of terrace and pediment gravel that locally mask underlying units. Focus was maintained instead on the distribution of the major depositional units that define the sedimentary framework of the foothills belt. Details of geomorphic evolution and soil development were not addressed. In many areas, thin unmapped surficial deposits of various kinds were laid down on successive erosional surfaces cut across sedimentary units during a long history of progressive denudation that gave rise to the present piedmont landscape (Davidson, 1973, p. E15). Capping soils have accordingly been developed over varying time intervals of exposure on surfaces of varying ages.

A legend for the accompanying geologic map follows references to the text. The designations used by previous workers for the various map units are discussed in the text, and presented in thumbnail form (Table 1) following the legend. Owing to the scarcity of definitive outcrops within the Catalina foothills belt, the reader should bear in mind that the placement of contacts between different depositional units by previous workers has inevitably varied somewhat, and few previously mapped contacts are identical to my own.

Stream Nomenclature

The terminology used for major stream courses requires comment:

(a) The trunk stream for Catalina foothills drainages is termed the "Rillito River", following currently available topographic quadrangle maps, although "Rillito Creek" has been common usage in the past (Barnes, 1960, p. 277; Peirce and Kresan, 1984; Pearthree and Baker, 1987; Kresan, 1988). The Spanish etymology of the name ("rillito" = "little river") is compatible with either designation. Following an old Spanish convention for naming streams, the name "Rillito" is not extended upstream beyond the juncture of Tanque Verde Wash with Pantano Wash.

(b) Tanque Verde Wash is designated alternately as "Tanque Verde Creek" or "Tanque Verde Wash" on currently available topographic maps, but the latter term is adopted here, by analogy with Agua Caliente Wash and Pantano Wash, for the ephemeral portion of the stream course below where it exits from the mountain front at the foot of Redington Pass.

(c) The streams that emerge from the bedrock gorges of Bear, Sabino, and Ventana Canyons are termed, on currently available topographic maps, Bear and Sabino Creeks but "Ventana Canyon Wash". This inconsistency is resolved here by adopting the parallel term "Ventana Creek" for the portion of that stream course below its exit from the mountain front.

(d) The piedmont stream course that parallels Pontatoc Road is termed Pontatoc Wash, by analogy with Pima Wash, which exits from Pima Canyon farther west along the mountain front.

Overall Piedmont Morphology

The Catalina foothills belt is formed by multiple geomorphic surfaces inclined gently downward from the foot of steeper bedrock slopes along the Santa Catalina mountain front toward the courses of the Rillito River and Tanque Verde Wash, which flow subparallel to the mountain front. Net gradients range from a low of 1.0%-1.5% (0.5°-0.9°) east of Bear and Sabino Creeks, through ~2.75% (~1.5°) in the drainages of Pontatoc and Pima Washes on the west, to a high of 4% (2.25°) near the center of the mapped area around Craycroft Road west of Ventana Creek. The upslope extent of the composite piedmont ramp is controlled by the position of the Catalina detachment fault, which structurally defines the northern edge of the sedimented Tucson basin. In general, Quaternary fan and pediment gravels fine from bouldery and cobbly deposits near the mountain front to cobbly and pebbly deposits, with intercalated sandy layers, near the Rillito River and Tanque Verde Wash.

The inclined surfaces include both the depositional surfaces of alluvial fans and the erosional surfaces of pediments, although the two kinds of geomorphic features are not readily distinguishable by eye at a distance, nor from the nature of gravels mantling their surfaces. Both kinds of features have been intricately dissected by younger ravines and arroyos, with highstanding piedmont benchlands stranded as remnant surfaces perched well above modern wash floors. West of the juncture of Pantano and Tanque Verde Washes, lateral erosion by the Rillito River has clipped the toe of the composite piedmont ramp to form steep cutbanks rising 25-50 m above the flank of alluvial flats along the fluvial valley. This erosional trimming of the toe of the piedmont ramp is responsible for much, though not all, of the dissection of the Catalina foothills by local streams tributary to the Rillito River. As fan and pediment toes are clipped by fluvial erosion, tributary streams must incise fan and pediment surfaces to reach grade with respect to the new position of the laterally migrating trunk stream. East of the juncture of Pantano Wash with Tanque Verde Wash near Craycroft Road, the toe of the sloping piedmont ramp merges almost imperceptibly with alluvial flats along Tanque Verde and Agua Caliente Washes.

Beyond the southern flank of the Rillito River alluvial flats, basin-fill deposits of the Tucson basin have been etched into multiple post-mid-Pleistocene terrace levels by successive phases of fluvial downcutting (Davidson, 1973; Anderson, 1987). Terrrace sediments, composed of detritus stranded in transit on erosional straths cut into basin fill, are typically 15-25 m in maximum thickness (Davidson, 1973, p. E32). The stream terraces are termed the University, Cemetery, and Jaynes terraces in order of decreasing age (Smith, 1938), but none of the three subregional terraces is present north of the Rillito River (McKittrick, 1988). Instead, the piedmont ramp forming the Catalina foothills terminates abruptly at ramp-toe bluffs cut at the flank of alluvial flats along the Rillito River.

Upstream from the juncture of Pantano and Tanque Verde Washes, immediately east of the limit of erosional truncation of the toe of the Catalina foothills piedmont ramp by lateral erosion, the Jaynes terrace level may be represented by a dissected stream

terrace along the north side of Tanque Verde Wash. The terrace flanks alluvial flats of Tanque Verde Wash as far east as the lowstanding ground between the mouths of Ventana and Sabino Creeks. As my study lacked the areal scope to confirm tentative correlation of this local terrace with the more widespread Jaynes terrace, the feature is here termed the Tanuri terrace (name taken from a local street and subdivision).

Rillito Valley Asymmetry

The fundamental cause of the asymmetry of the Rillito River valley is important to consider. Tilting of the floor of the Tucson basin downward to the north might be invoked to explain lateral erosion of the toe of the Catalina foothills sedimentary complex by the laterally migrating Rillito River, but the lack of comparable lateral erosion by Tanque Verde Wash, along trend to the east, is difficult to reconcile with that hypothesis. More likely is the alternate supposition that northward progradation of aggrading Quaternary basin fill delivered to the Tucson basin from the south by Pantano Wash and the Santa Cruz River is responsible for pressing the drainage course of the Rillito River against the toe of the Catalina piedmont ramp. The Pleistocene Fort Lowell Formation (Davidson, 1973) reaches thicknesses of 100-125 m beneath the Tucson basin (Anderson, 1987), and much of its volume may represent sediment fill poured across the basin from sources in the Pantano and Santa Cruz drainages. The distant headwaters of both streams lie in the Canelo Hills of southeastern Arizona, with the upper course of the Santa Cruz River looping through Mexico. The upper course of Pantano Wash, above its juncture with Mescal Arroyo, is termed Cienega Creek by longstanding convention.

The local presence of the Tanuri (=Jaynes?) terrace along the base of the Catalina piedmont ramp to the east of the juncture of Pantano Wash and Tanque Verde Wash can be taken as provisional confirmation that the asymmetry of the Rillito River valley farther downstream reflects northward progradation of sediment delivered to the Tucson basin by the Cienega-Pantano and Santa Cruz drainages. Preservation of the Tanuri terrace highlights the lack of comparable asymmetry for the valley of Tanque Verde Wash, which receives no major tributaries from the south. Westward termination of the Tanuri terrace along the north side of Tanque Verde Wash at its juncture with Pantano Wash suggests that sediment delivery to the Tucson basin by Pantano Wash is the most significant factor controlling the asymmetry of the Rillito River valley, with the Santa Cruz River serving principally as a throughgoing drain for water and entrained sediment in transit across the Tucson basin. This viewpoint is compatible with the morphology of the Tucson basin floor, which slopes continuously, at an average of ~8.75 m/km (0.5°), toward the Rillito River from the point where Pantano Wash exits from Cienega Gap. The floor of the northeastern corner of the Tucson basin is a sediment apron in the form of a half fan, confined by mountain spurs on the east, with its apex where Pantano Wash exits from Cienega Gap.

Principal Faults and Fault-Line Topography

No attempt was made during this study to map the many minor faults that cut the older Cenozoic sedimentary units exposed within the mapped area. Exposures of minor faults are wholly fortuitous, with most being identifiable only in randomly spaced road cuts. A systematic appraisal of the strikes and dips of visible minor faults might produce valuable insights into changing patterns of strain through time during the sedimentary evolution of the foothills belt, but was beyond the scope of my investigation. Pashley (1966, Figs. 26-28) reported generally northwesterly strikes (mainly N20W-N70W) and steep dips (mainly 60°-90°) for most minor faults in the Catalina foothills (~200 total attitude measurements), with dips to the southwest and to the northeast both common.

Three major normal faults are shown on the accompanying geologic map: (1) the Catalina detachment fault; (2) the supra-detachment Finisterra fault (new name), confined to the upper plate of the Catalina detachment system; and (3) the post-detachment Pirate fault, which is exposed only in the northwestern corner of the mapped area.

Catalina Fault

At intervals along the base of the Santa Catalina Mountains, deformed sedimentary units of the foothills belt are in fault contact with bedrock forming the lower plate of the Catalina core complex (Dickinson, 1991). All such contacts were mapped as segments of the Catalina detachment fault, although overprinting by younger fault structures may have modified some segments of the detachment fault to an uncertain extent. Bedrock directly below the fault is either mylonitic gneiss, or else chloritic breccia produced by retrograde alteration of mylonitic gneiss. The upper plate of the detachment system is composed of deformed Cenozoic strata in the Catalina foothills belt or, near the eastern edge of the mapped area, by non-mylonitic Precambrian basement and Cretaceous strata of the Bisbee Group.

The actual detachment surface, marked by a thin ledge of resistant microbreccia or cataclasite (Davis, 1987), was observed in only one locality, where the strike of the ledge is N65W, with a dip of 23° to S25W. This identifiable exposure of the detachment surface lies within a gated community just north of the east-west boundary between Sections 4 and 33 between the northern ends of Campbell Avenue and Alvernon Way (western map plat). From his multiple observations of the Catalina fault surface along the base of the Santa Catalina and Rincon Mountains, Pashley (1966, Table 4, p. 42) reported a mean dip (into the Tucson basin) of 30° ± 10° (S.D.; n=10).

Westward from the exposure of the detachment surface, the inferred course of the detachment fault, where buried beneath sediment cover, is shown on the accompanying geologic map by a dotted line extending to its buried juncture with the younger Pirate fault. A bedrock inselberg projecting above the surface of a surrounding alluvial fan just southeast of the mouth of Pima Canyon shows that the detachment fault to the west of Geronimo Wash follows a course that lies well into the foothills belt from the mountain

front. Pedimentation of the edge of the uplifted block below the detachment fault is here assumed to account for retreat of the mountain front from the trace of the detachment fault.

Eastward from the exposure of the microbreccia ledge, the Catalina detachment fault is discontinuously exposed near the base of the mountain front for approximately 5 km to the vicinity of Ventana Canyon. Eastward from Ventana Canyon for at least 12 km, to beyond the Catalina Highway, much of the abrupt face of the mountain front is interpreted as an eroded fault-line scarp where sediment fill overlying displaced strata of the upper plate of the detachment system is banked against eroded bedrock of the lower plate (Force, 1997). The exposure of the detachment fault crossing a projecting spur of the mountain front, in section 13 between Gibbon Springs and the Catalina Highway (eastern map plat), was not visited during this study, but was mapped by both Pashley (1966) and Davidson (1973).

Near where Agua Caliente Wash emerges from the mountain front approximately 2 km east of the Catalina Highway, the trend of the mountain front swings abruptly from east-west to north-south. The buried trace of the Catalina fault, masked by alluvial fan deposits and pediment gravels, presumably also swings southward parallel to the mountain front, but is not delineated on the accompanying geologic map because it lies at some indeterminate distance into the sedimented lowlands beyond pediments incised into the foot of the uplifted mountain block. The detachment fault emerges from cover in the vicinity of Rinconado Road near the eastern edge of the mapped area as a spoon-like fault segment overlain structurally by Precambrian granite and Mesozoic strata of the Bisbee Group. These pre-Cenozoic rocks of the upper plate of the detachment fault are cut by supra-detachment normal faults of the detachment system, and are exposed discontinously as far west as Wentworth Road. Exposures of the detachment fault along the front of the Rincon Mountains begin at Tanque Verde Guest Ranch, located approximately 2 km from the southeastern corner of the mapped area.

Finisterra Fault

The Finisterra fault (name taken from a gated community just west of Ventana Canyon) is a supra-detachment normal fault that terminates downward against the Catalina detachment fault. The same fault trend (unnamed) was depicted prominently by both Pashley (1966) and Davidson (1973) on their geologic maps of the Catalina foothills. As fault displacement was down to the southwest, sympathetic to movement along the structurally lower Catalina detachment fault, the Finisterra fault can be regarded as a late splay fault of the detachment system. The Finisterra fault trends to the southeast, from its juncture with the detachment fault, for 12-13 km until its trace passes beneath a broad expanse of alluvium near the juncture of Agua Caliente Wash with Tanque Verde Wash. From well data, Anderson (1987, Plate I, Section C-C') reported a subsurface fault offset of at least 300 m across the buried structure near the mouth of Agua Caliente Wash. Roughly comparable stratigraphic throw can be inferred from poorly constrained cross-sections constructed closer to the mountain front. Although the course of the Finisterra

fault was not traced south of Tanque Verde Wash, its southern continuation may delimit the western extent of pre-Cenozoic bedrock exposed in the upper plate of the Catalina detachment system along the Rincon Mountains foothills as far west as Twin Hills in east Tucson (Drewes, 1977).

Finisterra Escarpment

The topographic expression of the Finisterra fault is a quite remarkable feature of Catalina foothills geology. Post-displacement erosion has developed a discontinuous but prominent fault-line escarpment of antithetic character, facing to the northeast toward the upthrown footwall block. West of Ventana Creek, the escarpment bounds highstanding benchlands with surfaces that slope to the south-southwest away from the fault trace. East of Ventana Creek, however, erosion has apparently worn the escarpment back into the downthrown block, and the Finisterra fault trace lies within pedimented lowlands lying to the northeast of residual benchlands standing in the hanging wall of the fault. The fault trace, locally buried beneath stream alluvium, passes approximately through the juncture of Sabino and Bear Creeks. Farther southeast, the Finisterra escarpment is subdued, with Brush Hill and adjoining ridges forming its only topographic expression, lying parallel to a prominent photolinear interpreted as marking the fault trace.

There can be no doubt that Tertiary sedimentary strata (**Tsc**) underlying the high-standing lip of the escarpment are younger than the Tertiary sedimentary strata (**Tpa**) underlying lower ground to the northeast. Poorly consolidated gravels underpinning the uplands southwest of the fault are rich in clasts of mylonitic gneiss that are lacking or rare in more indurated conglomerates exposed beneath lower ground northeast of the fault. As argued cogently by both Voelger (1953) and Pashley (1966), and discussed more fully in the stratigraphic descriptions which follow, sedimentary units rich in gneiss clasts are uniformly younger than sedimentary strata lacking in clasts of mylonitic gneiss. Units bearing clasts of mylonitic gneiss were deposited after detachment faulting had produced a mountain front modern in guise, with forerange bedrock in the lower plate of the Catalina detachment system standing high above the Tucson basin, whereas units lacking gneiss clasts were deposited prior to, or during, detachment faulting, before tectonic denudation of the Catalina core complex had been achieved.

Development of the Finisterra escarpment without faulting, by simple erosional stripping of younger gravels from an older substratum to the northeast while preserving the younger gravels to the southwest, is precluded by bedding dips in roadcuts along Sunrise Drive and near Kolb Road southwest of the fault. The gravels immediately southwest of the fault dip northeast into the fault, defining a broad rollover structure adjacent to the fault, and would project downdip beneath older strata to the northeast in the absence of fault offset. As no exposure of the Finisterra fault could be found, its dip is unknown, but the rollover effect adjacent to the fault suggests that its surface is listric, dipping at variable angles that become shallower with depth to the southwest. At the time the gravels exposed southwest of the fault were deposited, older sedimentary strata northeast of the fault were apparently mantled by analogous younger gravels, for the

gravels southwest of the fault contain little or no non-mylonitic detritus recycled from older sedimentary strata now exposed in the upthrown block northeast of the fault.

Post-displacement reversal of topography across the Finisterra fault is here attributed to the more porous quality of the younger gravels on the downthrown southwestern side of the fault. Porous substrate can retard erosion by discouraging development of surface drainage. More indurated sediment supporting better developed surface drainage can somewhat paradoxically be eroded more rapidly than unconsolidated porous materials in which individual clasts are large enough to resist removal by small streams. An analogous effect promoted development of similar reversed or antithetic fault-line scarps, although on a smaller scale, along the Pirate fault at the western base of the Santa Catalina Mountains (Dickinson, 1994). Downfaulted Oro Valley basin fill composed of coarse megaclasts locally stands topographically higher than the surfaces of pediments cut into upthrown bedrock across the adjacent Pirate fault trace. In the case of the Finisterra fault-line escarpment, the erosive effects of vigorous streams emerging from the mountain front northeast of the Finisterra fault trace may have contributed to more effective erosional removal of the indurated strata exposed in the upthrown block adjacent to the fault

Multiple Stream Captures

Both Ventana Creek and Sabino Creek break through the Finisterra fault-line escarpment, suggesting that their courses through the highstanding benchlands to the southwest of the fault may have been antecedent to erosional development of the escarpment. The course of Ventana Creek is, however, diverted parallel to the foot of the Finisterra escarpment for a distance of approximately 5 km. Geographic relations suggest the hypothesis that the valley occupied now by Ventana Creek where it cuts through gravel benchlands lying southwest of the Finisterra fault may have been cut initially by Sabino Creek prior to capture of the latter drainage by tributary Bear Creek. Bear Creek emerges from the mountain front farther to the southeast where the Finisterra fault-line escarpment displays lower relief. As Bear Creek captured the upper drainage of Sabino Creek, the former lower course of Sabino Creek may have captured Ventana Creek, which emerges from the mountain front farther to the northwest where the Finisterra fault-line escarpment has maximum relief. The beheaded lower course of Ventana Creek is probably the broad blind valley extending southwest from near the junction of Kolb Road with Sunrise Drive. Provided these insights are valid, multiple stream captures shifted the courses of streams emerging from the mountain front directly upstream from the Finisterra escarpment successively toward the southeast, in the direction of decreasing erosional relief along the escarpment.

This notion brings into focus a satisfying concept of gradually evolving fault-line topography. When the Catalina detachment system was active, streams emerging from the steep mountain front that was developing along the contact between resistant bedrock and downfaulted basinal deposits at the Catalina detachment fault flowed orthogonally across the Finisterra splay fault. Fault scarps doubtless formed sporadically and locally along the

trace of the Finisterra fault, but vigorous streams debouching from the mountains probably kept the Finisterra fault largely buried under piedmont gravel deposits. If so, alluvial fans deposited on the downthrown side of the Finisterra fault probably merged upstream with gravel-masked pediments cut across older sedimentary strata on the upthrown side of the fault. Following termination of detachment faulting, downcutting by streams traversing the foothills belt began to etch out the present reversed or antithetic relief across the Finisterra fault trace. As a fault-line escarpment gradually evolved, antecedent piedmont streams were able to maintain courses through the benchlands developing southwest of the fault, but stream captures tended to behead benchland stream courses that became choked with gravels washed into them from progressively higher standing slopes along their flanks. With time, the stream captures served to connect upstream drainages emerging from the bedrock mountain front with benchland stream courses that lay progressively toward the southeast, the direction in which the relief of the fault-line escarpment declines.

Although alternate scenarios can be envisioned for the geomorphic evolution of the Finisterra fault-line escarpment and the stream courses that cross it, none seem as satisfactory. The most obvious is the possibility of a reversal in displacement late in Finisterra fault history. This behavior would have tended to erect a fault-scarp barrier across the courses of streams emerging from the mountain front, thus leading directly to the inferred stream captures, but there is presently no stratigraphic or structural evidence for late reversal of Finisterra fault movements. Also possible is the hypothesis that a master stream once flowed parallel to the full length of the Finisterra fault-line escarpment, from northwest to southeast, with the present stream courses traversing the highstanding benchlands southwest of the fault being attributed to headward erosion from the Rillito River, with consequent piecemeal stream capture of successive upstream drainages. This hypothesis is difficult to evaluate, but does not account well for the apparently beheaded lower course of ancestral Ventana Creek traversing benchlands lying southwest of the intersection of Kolb Road with Sunrise Drive, and is also difficult to reconcile with the distribution of coarse gravel deposits interpreted here as alluvial fans of ancestral Ventana and Sabino Canyons.

Ancestral Ventana-Sabino Alluvial Fans

Benchlands composed of nearly flat-lying gneiss-rich gravels (**QTvb**) flanking the valley of Ventana Creek, where that stream traverses ground lying southwest of the Finisterra fault, probably represent former alluvial fans built across the present trend of the Finisterra fault-line escarpment by ancestral streams emerging from Ventana and Sabino Canyons along the mountain front. The two largest erosional remnants of the benchlands, here termed the "Ventana Benchlands", form twin mesa-like features lying to the east and west of modern Ventana Creek (shown on eastern and western map plats, respectively). The gross shapes of the two benchland remnants in plan or map view may reflect initial fan morphology, with apparent apices and radiating ridges, etched out by subsequent erosion, pointing toward Ventana and Sabino Canyons (the western and eastern benchland mesas, respectively). The fan deposits may include clasts recycled from gravels that once capped the upthrown block that originally stood high on the northeast side of the Finisterra fault

prior to topographic reversal along the fault trace. From their size and unweathered character, however, most clasts in the ancestral alluvial fans were probably derived from direct erosion of bedrock in the Santa Catalina Mountains, and transported across the upthrown block adjacent to the Finisterra fault prior to development of an antithetic fault-line escarpment. At present, the drainage courses of Ventana Creek and Sabino Creek breaking through the residual uplands to the southwest of the Finisterra fault remain principal transit routes for sediment moving across the piedmont belt from the Santa Catalina Mountains toward the Rillito River.

The base of the inferred alluvial fan complex lies at elevations well below the surface of the dissected pediment complex extending along Craycroft Road to the west, where pedimentation truncated previously deformed and downfaulted piedmont gravels (**Tsc**). This topographic relationship suggests that the ancestral Ventana-Sabino alluvial fans, here termed the Ventana Benchlands fan complex (**QTvb**), backfilled a broad paleovalley cut previously across the Catalina foothills belt athwart the Finisterra fault trace. The surfaces of the ancestral alluvial fans, now stranded as benchlands at elevations more than 100 m above the floor of the modern valley of Ventana Creek, were apparently graded to the same general level as an erosional pediment forming essentially accordant benchlands farther west. Pashley (1966) regarded the unconformable base of the Ventana Benchlands fan complex (**QTvb**) as the "Rillito Surface", of inferred subregional extent (Morrison, 1991, p. 360), separating undeformed basin fill of the Tucson basin from older deformed units. A more local geomorphic origin for the contact, as a piedmont erosional surface flooring ancestral alluvial fans built downslope from Ventana and Sabino Canyons, is preferred here.

Pirate Fault

The Pirate fault, controlling the western face of the Santa Catalina Mountains, extends into the northwestern corner of the mapped area just east of Oracle Road. The exposed trace of the Pirate fault extends approximately one kilometer farther south than shown incorrectly by my previous mapping (Dickinson, 1994), for which the present map represents a belated correction. The Pirate fault is a post-detachment normal fault, down on the west, that places semi-consolidated basin fill of Oro Valley down against bedrock of the Catalina core complex in the footwall to the east. Though clearly younger than the Catalina detachment fault, the Pirate fault is also an inactive structure, lacking any sign of active fault scarps along its trace (Dickinson, 1994). Its only topographic expression, which is commonly subtle at best, is the result of local differential erosion of loose sediment in the hanging wall, as opposed to more resistant bedrock in the footwall.

Stratigraphic Nomenclature

In his pioneering study of the Catalina foothills, Voelger (1953) termed the tilted and faulted sedimentary strata underlying undeformed alluvial fans and pediment gravels the "Rillito Formation", a name never defined in the formal literature but later adopted by Pashley (1966). Voelger (1953) and Pashley (1966) both argued convincingly that the

percentage of clasts of mylonitic gneiss, derived from the lower plate of the Catalina detachment system, increases stratigraphically upward within their "Rillito Formation", and used the percentages of gneiss clasts in foothills gravels and conglomerates to infer the relative ages of different parts of the foothills sedimentary assemblage. On that basis, Voelger (1953) divided the "Rillito Formation" into "lower", "middle", and "upper" members, and Pashley (1966) described analogous, though not identical, subdivisions of the unit as "type I", "type II", and "type III" Rillito, respectively (abbreviated here as Rillito I, Rillito II, and Rillito III). Their work did not establish whether contacts between different elements of the "Rillito Formation" are gradational or unconformable (Pashley, 1966, p. 84), although Pashley (1966) reported local interlayering of conglomerates of Rillito II and Rillito III type at sub-meter scale in outcrops along Pontatoc Wash. Both Voelger (1953) and Pashley (1966) attributed (correctly in my view) the upward stratigraphic increase in gneiss clasts to gradual uncovering of the gneissic core of the Catalina core complex by tectonic denudation accompanying uplift of the present Catalina forerange. Recycling of clasts from older horizons into younger horizons of the "Rillito Formation" has locally produced mixed clast assemblages, but the gravels of dissected but undeformed alluvial fans and pediments overlying the deformed "Rillito Formation" are consistently dominated by white to gray clasts of mylonitic gneiss.

Mid-Tertiary Pantano Formation

Strata of the indurated Rillito I and Rillito II redbeds (lower and middle Rillito Formation of Voelger, 1953) were assigned by Drewes (1977) to the Pantano Formation (Brennan, 1957, 1962), with its type section in Cienega Gap south of the Rincon Mountains (Finnell, 1970). This usage was adopted (for their "Tos" unit) by Davidson (1973) and Anderson (1987), and is continued here. Exposures of the Pantano Formation (**Tpa**) along the Catalina foothills are lithologically indistingushable from exposures in Cienega Gap (Finnell, 1970; Drewes, 1977; Balcer, 1984). Andesitic to latitic lava of "Turkey Track porphyry" type (Cooper, 1961), interbedded with sedimentary rocks midway through the stratigraphic sequence in Cienega Gap (Balcer, 1984; Dickinson and Shafiqullah, 1989, Fig. 4; Dickinson, 1991, Fig. 55), has yielded a latest Oligocene K-Ar age of 25 Ma (Shafiqullah et al., 1978, #PED-40-63; Reynolds et al., 1986, #681). The age range of the type Pantano Formation is accordingly regarded here as late Oligocene to early Miocene.

Post-Pantano Cenozoic Strata

Davidson (1973, p. E20-E25) and Anderson (1987, p. 10-12) assigned tilted and faulted foothills strata, younger than the Pantano Formation and corresponding generally to the "upper" Rillito of Voelger (1953) and Rillito III of Pashley (1966), to the "Tinaja Beds" (misspelled "Tinaga Beds" in the legend of the Davidson geologic map). The name was derived from implied correlation with the "Formation of Tinaja Peak" along the southeastern flank of the Sierrita Mountains at the southwestern edge of the Tucson basin. The "Formation of Tinaja Peak" is largely composed, however, of rhyodacitic to andesitic volcanics, with an intervening middle sedimentary member, and has yielded Oligocene K-

Ar ages (n=3) of 24-27 Ma (Cooper, 1973; recalculated according to Dalrymple, 1979). The isotopic ages imply correlation of the "Formation of Tinaja Peak" with some lower to middle part of the Pantano Formation of Cienega Gap, and suggest that it is distinctly older than strata unconformably overlying the Pantano Formation and termed "Tinaja Beds" during past work in the Catalina foothills.

Strata of the "Formation of Tinaja Peak" are only slightly younger than the Helmet Fanglomerate, exposed ~10-12 km to the north-northeast on the northeastern flank of the Sierrita Mountains (Cooper, 1973). Felsic tuff, and lava of "Turkey Track porphyry" type, both intercalated within the Helmet Fanglomerate, have yielded isotopic ages of 29-31 Ma (Reynolds et al., 1986, #836 & #885). The Helmet Fanglomerate structurally overlies a detachment fault that transported it ~10-12 km to the north-northwest with respect to the lower plate of the detachment system (Lipman and Fridrich, 1990; Dickinson, 1991, p. 8 and references thereto). The Helmet Fanglomerate and the "Formation of Tinaja Peak", which rests unconformably on pre-Tertiary rocks in the lower plate of the detachment system, were probably deposited as parts of the same mid-Tertiary volcanosedimentary succession, generally correlative with the Pantano Formation of Cienega Gap. Detachment faulting then offset the Helmet Fanglomerate in the upper plate of the detachment system from the "Formation of Tinaja Peak" in its lower plate.

Although the designation "Tinaja Beds" has been applied extensively to subsurface sediments beneath the Tucson basin (Anderson, 1987, p. 10-12), the name "Tinaja", linked irrevocably to the unit mapped along the flank of the Sierrita Mountains (Cooper, 1973), is here deemed inappropriate for exposed units within the Catalina foothills belt on both lithostratigraphic and chronostratigraphic grounds. Accordingly, a local designation ("Swan-Craycroft gravels", **Tsc)** has been adopted for mapped exposures of tilted and faulted strata ("Tinaja=Tinaga Beds") distinctly younger than the Pantano Formation (**Tpa**). Correlation of exposed sedimentary units in the Catalina foothills with buried sedimentary units in the subsurface of the Tucson basin was beyond the scope of this study.

As discussed in succeeding sections, Davidson (1973) and Anderson (1987) applied the term Fort Lowell Formation (Davidson, 1973) to selected strata of inferred late Pleistocene age in the Catalina foothills. Davidson (1973, p. E15) inferred that the Fort Lowell Formation, composed of surficial deposits with a stated maximum thickness of 100-125 m, overlies the "Rillito Surface" of Pashley (1966). Deposits assigned by previous workers to the Fort Lowell Formation include unconsolidated alluvial fan and pediment gravels of varying ages in detail, and assigned here to multiple map units as discussed below.

Pre-Pantano Mesozoic Strata

In my judgment, previous workers misinterpreted local exposures of Mesozoic redbeds near the eastern edge of the mapped area as Cenozoic redbeds of the Pantano Formation. The strata are here assigned instead to the Cretaceous Bisbee Group (**Kbi**),

and probably represent the fluvial Willow Canyon Formation. Redbed mudstones within the unit are much more indurated and fractured than Pantano mudstones, and intercalated sandstones are both quartz-rich and much better sorted than typical Pantano sandstones of more lithic character. Conglomerate, so common in the Pantano Formation, is absent. Exposures of Bisbee Group within the mapped area were depicted as Rillito I (~Pantano Formation) by Pashley (1966), and as Pantano Formation ("Tos") by Davidson (1973). Creasey and Theodore (1975) later designated the same outcrops as "Ts" (red-bed sedimentary rocks of Tertiary? age), and used the same designation for correlative redbeds exposed in lower Edgar Canyon, east of the Santa Catalina Mountains at the northern tip of the Buehman tiltblock near the San Pedro River. The latter outcrops are also known now to represent the Bisbee Group (Bykerk-Kauffman, 1983; Dickinson, 1991, 1992, 1998), although a recently released compilation map (Drewes, 1996, Pl. 2), perpetuating older usage, depicts them incorrectly as "Tsv" (undivided Eocene to Miocene sedimentary and volcanic rocks). Personal reconnaissance just outside the mapped area suggests that folded redbeds exposed along Speedway Boulevard, south of Tanque Verde Wash and 2-3 km east of Wentworth Road, along the boundary between sections 3 and 10 (T. 14 S., R. 16 E.), are also Bisbee Group, rather than Pantano Formation, as mapped by Drewes (1977). Distinction between redbeds of the Pantano Formation and the Bisbee Group requires close attention to lithologic details.

Foothills Sedimentary Assemblages

The sedimentary assemblages of the Catalina foothills are discussed here from youngest to oldest, as if peeling off successive layers of piedmont paint. Table 2 (end of text) presents a summary of depositional history. As no fossil collections or radiometric ages are available for Cenozoic or Mesozoic strata exposed within the mapped area, all age assignments are inferential, and subject to revision with more complete information.

Holocene Alluvium

Quaternary alluvium (**Qal**) was mapped along the northern sides of the valley of the Rillito River and Tanque Verde Wash, and up major tributary drainages (Pima Wash, Sabino-Bear Creeks, Agua Caliente Wash) where expanses of alluvium are broad. The map unit is essentially identical to the "Qal" (alluvium along drainage channels) of Banks (1976) and Pashley (1966), and to the "Qs_3" (stream and floodplain alluvial deposits) of Davidson (1973), although previous workers mapped alluvial deposits along minor wash floors that were ignored during this study. From well bores, the maximum thickness of Holocene alluvium beneath the thalwegs of Tanque Verde Wash and the Rillito River is 10-20 m (Pashley, 1966, p. 134). The Holocene alluvium (**Qal**) of this study corresponds to Unit Y (active stream channels) of Pearthree et al. (1988).

Pleistocene (Younger) Piedmont Gravels

Three dissected alluvial fan complexes, grading locally to thin pediment cover on older substratum, are incised below the surfaces of older alluvial fans and pediments, and

are inferred from their limited degree of dissection to be of Pleistocene age. The surfaces of all three fan-pediment complexes stand topographically lower than any elements of the Catalina piedmont ramp, other than washfloor alluvium and isolated patches of terrace gravel perched on the flanks of local ravines and stream courses. The gravelly sediments of all three fan depositional systems are essentially unconsolidated, and are composed dominantly of mylonitic gneiss clasts. From west to east, they include the Pima Canyon fan complex (**Qpc**), the Finger Rock fan complex (**Qfr**), and the Snyder-Soldier fan complex (**Qss**), with the first two names taken from local feeder drainages and the latter from roads built across the depositional surface. Gravels of all three depositional units onlap across the Catalina detachment fault to rest locally on bedrock of the Santa Catalina Mountains. As the three complexes are nowhere in mutual contact, relative ages are uncertain, and the three units are probably coeval in part. As mapped, each may also include modern fan sediment that has poured over uphill segments of the dissected fan surfaces from the adjacent steep mountain front. From the differing degrees of dissection of associated fan surfaces and topographic relations of the three fan-pediment systems to the mountain front and to other sedimentary components of the Catalina piedmont ramp, the bulk of constituent gravels are thought mainly to have been deposited in the following approximate order, from oldest to youngest:

(1) Pima Canyon fan complex: The Pima Canyon fan complex (**Qpc**; western map plat), although dissected by multiple ravines, still retains its fan morphology, extending downhill to the edge of alluvium along the Rillito River from a principal apex at the exit of Pima Canyon from the mountain front, and from subordinate apices located at the mouths of gulches farther west along the mountain front. The western flank of the Pima Canyon fan complex overlaps the trace of the Pirate fault. Clasts of white to pale gray mylonitic gneiss dominate the gravel fraction of its sediment, but friable sandy layers intercalated with gravels near its toe are locally discolored to tawny and reddish hues. On the east, the flank of the Pima Canyon fan complex (**Qpc**) was deposited along the base of steep slopes previously carved by incision of the older Campbell Avenue fan complex (**QTca**). This "topographic unconformity", against which gravels of the Pima Canyon fan complex are banked laterally, is prominent and clearcut near the mountain front (north of Skyline Drive), but becomes progressively more subdued southward toward the Rillito River, and can be traced only with difficulty and some uncertainty between Skyline Drive and River Road. The large bulk of the Pima Canyon fan complex (**Qpc**), as opposed to the limited areal extent and comparatively thin sediment profile of the Finger Rock fan complex (**Qfr**), exposed not far to the east, may stem in part from the much larger size of the Pima Canyon drainage basin within the Santa Catalina Mountains, as compared to the drainages of the small ravines and gulches feeding the Finger Rock Fan complex (**Qfr**), and in part from a longer duration of fan sedimentation.

The remnant surface of the Pima Canyon fan complex (**Qpc**) slopes at ~2.6° (45 m/km) near the mountain front, but declines to ~1.3° (20-25 m/km) near the Rillito River. Measured bedding attitudes range from horizontal to 3°, broadly parallel to the surface slope. The topographic relief between the remnant surface of the dissected Pima Canyon fan complex (**Qpc**) and the remnant surface of the older, more dissected Campbell Avenue

fan complex (**QTca**) is ~50 m near the mountain front, but declines to 10-15 m midway between the mountain front and the Rillito River, and to only 5-10 m near the Rillito River. Progressive reduction in the topographic relief between the two dissected fan surfaces stems from greater surface slope of the older fan complex (see below). The factors that controlled deep incision and partial removal of the Campbell Avenue fan complex (**QTca**) prior to construction of the younger Pima Canyon fan complex (**Qpc**), and the factors that later triggered deposition of the latter, remain unknown with present information.

(2) Finger Rock fan complex: Along the mountain front below Finger Rock and Pontatoc Canyons, and Pontatoc Ridge, gravel cover of variable but modest thickness, rich in gneiss clasts, is exposed beneath the surfaces of local benchlands perched above ravines eroded into underlying exposures of the Pantano Formation (**Tpa**). This Finger Rock fan complex (**Qfr**; western map plat) is inset topographically well below the degraded surface of the Campbell Avenue fan complex (**QTca**), and was apparently constructed within a tract of ground from which deposits of the Campbell Avenue fan complex (**QTca**) had previously been stripped by erosion of Pontatoc Wash and its tributaries. Delivery of coarse sediment from the steep mountain front into the severely dissected amphitheater-like depression eroded from older units by the drainage of Pontatoc Wash was presumably the cause of renewed fan sedimentation. The irregular downhill edge of present exposures of the Finger Rock fan complex (**Qfr**) is partly a line of erosional truncation, where ravines working headward from the Rillito River or Pontatoc Wash have incised the foothills belt, and partly the downhill limit of progradational fan lobes that advanced downstream into previously eroded valleys like icing poured over a partly eaten cake. The Finger Rock fan complex (**Qfr**) has an inherently irregular base above which prograding fan gravel was aggraded against the flanks of protruding hills eroded from the underlying Pantano Formation (**Tpa**). The base of the gravel deposits surrounding residual hills is probably in part a pediment surface cut across exposures of the Pantano Formation (**Tpa**).

The remnant surface of the Finger Rock fan complex (**Qfr**) slopes at angles of ~4.5° (80 m/km) near the mountain front and ~2.25° (40 m/km) near the downhill limit of the fan complex. No reliable bedding attitudes could be measured in the constituent fan gravels, but dips are assumed to be comparable to the surface slope. The topographic relief between the remnant surfaces of the Finger Rock fan complex (**Qfr**) and the older Campbell Avenue fan complex (**QTca**) ranges from 35-45 m near the mountain front to only 15-25 m near the lobate toe of the younger fan complex.

(3) Snyder-Soldier fan complex: In a broad curving arc from Ventana Canyon on the west to beyond Agua Caliente Spring and Park on the east, a compound fan and pediment complex extends along the base of the mountain front, with a general width of 1.0-2.5 km. Surface slopes of this Snyder-Soldier fan complex (**Qss**; mainly eastern map plat) range from an average of ~2° (35 m/km) west of Sabino Creek to 1.3°-1.4° (20-25 m/km) farther east. In places, the depositional system is clearly incised by modern drainages, but in other places its toe grades almost imperceptibly into alluvial flats along

major washes. The substratum of the depositional system is principally the Pantano Formation (**Tpa**), and exposures of the latter unit peek as inliers from beneath the surrounding fan sediment at multiple localities. Gneiss clasts derived directly from the Santa Catalina Mountains predominate, however, in the overlying fan deposits. The Snyder-Soldier fan complex (**Qss**) overlaps the trace of the Finisterra fault, indicating that its deposition postdated development of the Finisterra erosional escarpment.

Previous Mapping: The Pima Canyon fan complex (**Qpc**) has been mapped variously as "Qtb-Qtbc" (basin fill or basin fill locally veneered by Cemetery terrace deposits) by Pashley (1966), as "Qs" (undifferentiated alluvial deposits of Fort Lowell and younger age) by Davidson (1973), as "Qtg" (terrace gravel) by Banks (1976), and as "Qf" (Pleistocene Fort Lowell Formation) by Anderson (1987). All these designations are compatible with an inferred Pleistocene age.

The Finger Rock (**Qfr**) and Snyder-Soldier (**Qss**) fan complexes were depicted as "Q_j" and "Qs_2" (both symbols signifying Jaynes terrace deposits) by Pashley (1966) and Davidson (1973), respectively. As neither feature can be construed topographically as a stream terrace, the designation as "Jaynes terrace deposits" presumably stemmed from topographic correlation of an ancestral piedmont landscape, defined by the two features, with the level of basin incision represented by the Jaynes terrace beside the Rillito River. Banks (1976) mapped the Finger Rock fan complex (**Qfr**) as "Qtg" (terrace gravel), presumably from the topographic position of its remnants on benches standing above Pontatoc Wash, and the Snyder-Soldier fan complex (**Qss**) as "Qs" (older alluvium and fan deposits). At the small scale of his map, Anderson (1987) did not distinguish either depositional unit from the underlying Pantano Formation (**Tpa**).

All three Pleistocene fan complexes were shown mostly as Unit M (inactive alluvial fan and terrace deposits) by Pearthree et al. (1988), with segments of the Pima Canyon fan complex (**Qpc**) depicted as Unit T (exhumed basin fill deposits).

Pliocene (?) – Pleistocene (Older) Piedmont Gravels

From west to east, more deeply dissected gravels of the Campbell Avenue fan complex (**QTca**), the Ventana Benchlands fan complex (**QTvb**), and the Deep Well Ranch bench-gravel complex (**QTdw**), the latter apparently representing dissected pediment gravel, are probably also Pleistocene in age, but could be as old as Pliocene, at least in part, by analogy with depositional units in adjoining basins of southern Arizona. No evidence for structural deformation of the Pliocene(?)-Pleistocene gravel units was detected during this study, and all measured dips on constituent beds lie within the range (<3°) expected for initial dips. Within a gated community in the deep ravine between the northern ends of Campbell Avenue and Alvernon Way, Pashley (1966), Banks (1976), and Davidson (1973) mapped the steeply inclined east-west contact between the Campbell Avenue fan complex (**QTca**) and the Pantano Formation (**Tpa**) in the northern part of Section 4 as a fault, but no evidence of faulting could be detected at the contact, nor are adjacent strata visibly disrupted. The contact is accordingly regarded here as a buttress

unconformity, akin to the somewhat less abrupt buttress unconformity exposed farther south down the same ravine. As in the case of the younger Pleistocene fan complexes, the lack of mutual contact relationships precludes definitive assignment of relative ages to the Pliocene(?)-Pleistocene gravel units, but general considerations suggest the following order of age, from oldest to youngest:

(1) Ventana Benchlands fan complex: Gravels composed dominantly of gneiss clasts forming benchlands ("Ventana Benchlands") that flank the lower course of Ventana Creek are regarded here (see above) as ancestral alluvial fan deposits of Ventana and Sabino Canyons. The Ventana Benchlands fan complex (**QTvb**; near east edge of western map plat and west edge of eastern map plat) was probably constructed within a broad paleovalley cut across the trace of the Finisterra fault, and through deformed piedmont gravels of the Swan-Craycroft gravels (**Tsc**) exposed southwest f the fault. Deposition is inferred to have occurred after fault displacement but prior to development of the Finisterra erosional escarpment, which now limits the Ventana Benchlands fan complex (**QTvb**) on the northeast. The gravels of the fan complex are deeply dissected, with some exposed on detached summits as outliers from the principal benchlands underlain by the fan gravels.

The area of exposure of the Ventana Benchlands fan complex (**QTvb**) is bordered on the west by exposures of deformed Swan-Craycroft gravels (**Tsc**), which are beveled by an erosional pediment surface (upper or Craycroft pediment level; see below) that is broadly accordant with the upper surface of the Ventana Benchlands fan complex (**QTvb**). The aggradational fan complex and the degradational pediment surface were apparently components of the same ancestral piedmont landscape. The remnant surface of the Ventana Benchlands fan complex (**QTvb**) slopes away from the mountain front at an average of perhaps ~1.5° (25 m/km), and bedding attitudes obtained from constituent gravels range from horizontal to 3°.

(2) Campbell Avenue fan complex: As the Campbell Avenue fan complex (**QTca**; western map plat) overlaps the Catalina fault, it is clearly a post-detachment depositional feature, but was deeply dissected prior to deposition of the Pleistocene Pima Canyon (**Qpc**) and Finger Rock (**Qfr**) fan complexes, which flank remnants of the Campbell Avenue fan complex (**QTca**). Lithologically, sediments of the Campbell Avenue fan complex (**QTca**) closely resemble younger sediments of the Pima Canyon fan complex (**Qpc**), with gravel rich in gneiss clasts dominant and local reddish or tawny discoloration of sandy layers. The Campbell Avenue fan complex (**QTca**) was deposited unconformably above previously faulted and variably tilted strata of the Pantano Formation (**Tpa**) along an irregular contact that is well exposed in a roadcut on Sunrise Drive just east of its intersection with Campbell Avenue. Within drainages east to Pontatoc Wash, sediment of the Campbell Avenue fan complex (**QTca**) has been widely stripped by erosion from the underlying Pantano Formation (**Tpa**), but local outliers of gneiss-rich fan sediment on local mesa tops record the former presence of the Campbell Avenue fan complex (**QTca**) across the ground between Campbell Avenue and Pontatoc Wash.

A broad downhill remnant of the Campbell Avenue fan complex (**QTca**) extends as far east as Pontatoc Wash between Sunrise Drive and River Road, and confirms that uphill segments of the fan complex did once occupy much of the drainage of Pontatoc Wash and smaller ravines to the west as far as the mountain front. Correlative fan sediment may also have extended westward from present remnants of the Campbell Avenue fan complex (**QTca**) across the area now occupied by the younger Pima Canyon fan complex (**Qpc**). The present apparent apex of the Campbell Avenue fan complex (**QTca**) on a ridge beneath Rosewood Point in the Catalina forerange is probably a false apex, representing the most uphill remnant of a fan complex fed mainly by canyons lying farther to the east and west. The remnant surface of the Campbell Avenue fan complex (**QTca**) slopes at ~3° (50 m/km) near the mountain front (above Sunrise Drive) and at 1.5°-2.0° (25-35 m/km) near the Rillito River (below Sunrise Drive). Dips measured on bedding in constituent gravels range from 2° to 3°, subparallel to the remnant fan surface.

Along the lower course of Pontatoc Wash, the eastern flank of the Campbell Avenue fan complex (**QTca**) is banked against eroded remnants of the deformed and more indurated Swan-Craycroft gravels (**Tsc**). Prior to or during deposition of the Campbell Avenue fan complex (**QTca**), the previously deformed Swan-Craycroft gravels (**Tsc**) were deeply eroded, with widespread development of a pedimented surface (lower or Swan pediment level; see below) that appears topographically accordant with the dissected surface of the Campbell Avenue fan complex (**QTca**), and probably formed part of the same ancestral piedmont landscape.

(3) Deep Well Ranch bench-gravel complex: East of Agua Caliente Wash, low benchlands lying generally between Redington and Fort Lowell Roads, and traversed by Soldier Trail, are underlain by a thin veneer of dissected gneiss-rich gravel that rests unconformably on exposures of the Pantano Formation (**Tpa**). The depositional contact below the gravels is well displayed in roadcuts along Soldier Trail near its intersection with Redington Road. These bench gravels, termed the Deep Well Ranch bench-gravel complex (**Qtdw**; eastern map plat) from Deep Well Ranch on a gravel-capped interfluve, are distinctly older than the Snyder-Soldier fan complex (**Qss**), which banks against topographic declivities flanking gravel-capped benches. Exposures of Pantano Formation (**Tpa**) and Bisbee Group (**Kbi**) are locally present on slopes below the bench gravels but above the fan surfaces. The bench gravels are interpreted here as remnants of the gravel cover of a pediment surface that was developed locally along the mountain front, although the thickness of the bench gravels is locally excessive for an active pediment surface, and may reflect construction of supra-pediment alluvial fans atop an inactive pediment. The gravel benches slope at 1°-1.5° (15-25 m/km) away from the mountain front.

Previous Mapping: Pashley (1966), Davidson (1973), and Anderson (1987) included the Campbell Avenue fan complex (**QTca**) within the same map unit as the younger Pima Canyon fan complex (see above). Banks (1976) made a distinction, however, between the older Campbell Avenue fan complex ("QTg-QTgc") and the younger Pima Canyon fan complex ("Qtg"). Pashley (1966), Davidson (1973), and Banks (1976) all included the Ventana Benchlands fan complex (**QTvb**) within the same map

unit as the Campbell Avenue fan complex (**QTca**). Pearthree et al. (1988) showed the Ventana Benchlands fan complex (**QTvb**) and part of the Campbell Avenue fan complex (**QTca**) as Unit T (exhumed basin fill deposits), and part of the latter as Unit M (inactive alluvial fans and terrace deposits). Pashley (1966) and Davidson (1973) both mapped the Deep Well Ranch bench-gravel complex (**QTdw**) as deposits of the post-mid-Pleistocene Cemetery terrace ("Q_c" and "Qs_1", respectively), implying that the piedmont gravel bench was graded to the level of the Cemetery terrace within the Tucson basin, and Pearthree et al. (1988) showed the complex as Unit O (dissected piedmont fan-terrace remnants).

Miocene (?) Swan-Craycroft Gravels

Deformed and pedimented gravels and semi-consolidated conglomerates of probable Tertiary (Miocene and/or Pliocene) age underlie topographically complex benchlands extending from the drainage of Pontatoc Wash (on the west) eastward past Ventana and Sabino Creeks to the general vicinity of the Catalina Highway on the east (spanning the join between eastern and western map plats). These Swan-Craycroft gravels (**Tsc**), with the name taken from Swan and Craycroft Roads, are variably consolidated deposits with an indurated brownish matrix. Clasts are dominantly mylonitic gneiss and dark schist or semischist in variable proportions locally. Near the Catalina Highway, non-mylonitic clasts reworked from the directly subjacent Pantano Formation are also common to abundant locally.

West of Ventana Creek (western map plat), the Swan-Craycroft gravels (**Tsc**) underlie deeply dissected pediments with locally preserved surfaces standing at two different levels (upper "Craycroft" and lower "Swan" pediments), and also underlie the younger Tanuri stream terrace incised into the toe of the Catalina piedmont ramp along the flank of Tanque Verde Wash. East of Ventana Creek (eastern map plat), Swan-Craycroft gravels (**Tsc**) underlie variably eroded low hills of less distinct morphology. The only exposures preserved on the upthrown northeast side of the Finisterra fault form a gentle cuesta with its irregular crest on Mount Pleasant and the essentially accordant hill top located near the intersection of the Catalina Highway with Houghton Road (eastern map plat).

Minor faults cut the Swan-Craycroft gravels (**Tsc**) in numerous roadcuts, and dips range upward to >25°, although dips of the order of 10°-15° are more common. The surfaces of piedmont benchlands developed by erosion across Swan-Craycroft gravels (**Tsc**) have superficial appearances similar to the residual surfaces of dissected alluvial fans, but clearcut angular discordances between benchland topographic surfaces sloping at <5° and bedding which dips typically at 7°-18° within the underlying Swan-Craycroft gravels (**Tsc**) shows that the accordant benchland summits are remnants of pediment rather than fan surfaces. In many areas, locally divergent dip patterns document internal deformation of the unit, which was also offset by both the Catalina detachment fault and the supra-detachment Finisterra splay fault. From the inferred ages and structural relationships of the underlying and overlying sedimentary units, the Swan-Craycroft gravels (**Tsc**) were probably deposited between early Miocene and mid-Pliocene time.

Pashley (1966, p. 90) inferred that they may be broadly correlative with the post-mid-Miocene (Dickinson, 1991, 1998) Quiburis Formation of the San Pedro trough, but offset by the Catalina detachment fault suggests that they are actually older Miocene in age. The full age range of strata assigned here to the Swan-Craycroft gravels (**Tsc**) is uncertain, and they could vary considerably in age. Internal scour surfaces, or even unconformities of modest angularity, could well have gone undetected in poorly exposed benchlands.

Despite local dip reversals and areas of distinctly gentler or steeper dips, the prevalent attitudes within Swan-Craycroft gravels (**Tsc**) lie in the range of 10° ± 4° to the south-southwest, directly away from the trend of the Catalina and Finisterra faults. This structural pattern suggests that the Swan-Craycroft gravels (**Tsc**) were deposited as an alluvial fan complex built into the northern flank of the Tucson basin during the late stages of detachment faulting after the mylonitic basement of the Catalina forerange had been exposed to erosion by tectonic denudation. Attitudes of clast imbrication within the Swan-Craycroft gravels (**Tsc**), though not measured systematically during this study, seem generally compatible with sediment transport to the south or southwest. Comparatively gentle dips (2°-9°) near and west of Swan Road, just uphill from River Road, imply that the southwesternmost preserved part of the fan complex, most distant from the Finisterra fault, was least deformed. Within a belt approximately a kilometer wide adjacent to the Finisterra fault, bedding in Swan-Craycroft gravels (**Tsc**) of the hanging wall rolls over systematically to dips of 10°-25° toward the east or northeast (into the fault). The rollover effect dies out toward the southeast, away from the juncture of the Finisterra fault with the Catalina detachment fault, and may reflect lesser displacement across the Finisterra fault toward the southeast, where exposures of the Swan-Craycroft gravels (**Tsc**) are present on both sides of the fault.

Swan-Craycroft Pediments: Two topographically distinguishable pediment levels were cut across deformed Swan-Craycroft gravels (**Tsc**) in dissected benchlands between Pontatoc Wash and Ventana Creek (western map plat). Each of the two pediments may be a compound erosional surface, for the degree of preservation of pediment remnants is in neither case sufficient to establish exact accordance of surface elevations. Remnants of the higher (Craycroft) pediment level on the east (along and east of Craycroft Road) are generally accordant with the surfaces of benchlands capping the Ventana Benchlands fan complex (**QTvb**), located still farther to the east, whereas remnants of the lower (Swan) pediment level on the west (to either side of Swan Road) are generally accordant with the degraded surface of the Campbell Avenue fan complex (**QTca**), located still farther to the west. These topographic relationships are compatible with the provisional interpretation that the Craycroft and Swan pediment levels represent successive stages in erosional downcutting of the Catalina foothills belt, with each pediment level formed as part of an ancestral piedmont landscape that also included aggradational alluvial fans (Ventana Benchlands and Campbell Avenue fan complexes, respectively) that were graded to the same general levels as the erosional pediments. The seemingly correlative ancestral fans and pediments were positioned laterally, side by side, along the mountain front. If correct, the correlation of pediment and fan surfaces confirms that the Campbell Avenue fan complex (**QTca**) is somewhat younger, at least in terms of the final constructional age of

its depositional surface, than the Ventana Benchlands fan complex (**QTvb**), for the Swan pediment level is clearly younger than the Craycroft pediment level.

The two pediment levels have broadly comparable slopes, but the intervening topographic relief decreases downslope, from 35-45 m near the mountain front to ~25 m midway along the slope of the Catalina piedmont ramp, and perhaps to only 10-15 m near the Rillito River. The remnant surface of the Craycroft (upper) pediment level slopes 2.5°-3.5° (45-60 m/km) near the mountain front, ~1.75° (30 m/km) midway down the piedmont ramp, and ~1.5° (25 m/km) near the Rillito River. The remnant surface of the Swan (lower) pediment level slopes ~3° (50-55 m/km) near the mountain front, ~2° (35 m/km) midway down the piedmont ramp, and ~1.5° (25 m/km) near the Rillito River.

The higher (Craycroft) pediment level extends essentially to the lip of the Finisterra escarpment, indicating that it was cut across the deformed alluvial fan complex of the Swan-Craycroft gravels (**Tsc**) prior to erosional development of the fault-line escarpment. By contrast, the eastern edge of the lower (Swan) pediment level extends to the base of the mountain front immediately west of the juncture of the Finisterra and Catalina faults. These relationships suggest a rationale for the successive development of two discrete pediment surfaces. The older and higher Craycroft pediment probably formed at a time when the Catalina piedmont ramp extended unbroken across the trace of the Finisterra fault to a mountain front then upslope to the northeast in the vicinity of modern Ventana and Sabino Canyons, whereas the younger and lower Swan pediment was not formed until some time after erosional development of the Finisterra escarpment had topographically separated the piedmont benchlands west of Ventana Creek from the mountain front to the northeast. This change in the boundary conditions affecting sediment delivery and resulting stream gradients across the piedmont landscape may have been the factor that dictated a shift in the level at which effective pedimentation of the piedmont belt could be achieved, and may thereby have been responsible for the development of two discrete pediment levels. Remnants of the higher (Craycroft) pediment are now stranded along and near the Finisterra escarpment, with remnants of the lower (Swan) pediment representing incision that later bit into the Swan-Craycroft gravels (**Tsc**) from the west, along the flank of piedmont drainages ancestral to modern Pontatoc Wash and its tributaries.The main stem of modern Pontatoc Wash evidently developed along the morphological join or sulcus between the Campbell Avenue fan complex (**QTca**) and the roughly coeval Swan pediment surface lying to the east. A broad uphill segment of the Campbell Avenue fan complex (**QTca**) was subsequently removed by erosion from the amphitheater-like depression near the mountain front, along and west of Pontatoc Wash, where extensive inliers of the older Pantano Formation (**Tpa**) are now exposed.

Tanuri Terrace: Near Tanque Verde Wash, the Tanuri (Jaynes?) stream terrace was also incised into tilted Swan-Craycroft gravels (**Tsc**). Although a veneer of terrace sediment is present locally, beds below the terrace surface, which is evidently a strath terrace, dip at angles of 7°-18° where modern ravines that dissect the terrace expose outcrops of the gravels underlying the terrace. The seemingly anomalous hillock atop

the Tanuri terrace just east of Craycroft Road is composed of spoilage from excavations made into the hillside above the terrace during development of the shopping center north of adjacent River Road.

Basal Contact: Although the basal contact is nowhere well exposed, the Swan-Craycroft gravels (**Tsc**) are inferred to overlie the Pantano Formation (**Tpa**) with angular unconformity in the following localities: (a) just west and southwest of the intersection of Skyline Drive with Swan Road (western map plat), where Swan-Craycroft gravels dip 8° to the east off Pantano exposures in which bedding dips 10°-18° to the south; (b) just west of the intersection of Sunrise Drive with Pontatoc Road (western map plat), where Swan-Craycroft gravels dipping 3° to the south abruptly overlie beds dipping 20° to the west in the underlying Pantano Formation; and (c) along the Catalina Highway just east of its intersection with Houghton Road (eastern map plat), where basal Swan-Craycroft gravels, which locally include abundant non-mylonitic clasts reworked from the underlying Pantano Formation, dip 2°-3° to the south above beds dipping 10°-25° to the southeast and to the southwest in the subjacent Pantano Formation.

Outcrops: The most informative outcrops of the Swan-Craycroft gravels (**Tsc**) are located in a roadcut on Skyline Drive just west of Swan Road, in multiple hillside cuts behind shopping centers and apartment complexes near the intersection of Swan Road with Sunrise Drive, in a roadcut at the intersection of Craycroft Road with Sunrise Drive and in roadcuts farther north along Craycroft Road near the mountain front, in the high roadcuts along Sunrise Drive between Craycroft and Kolb Roads, in roadcuts along Kolb Road opposite the entrance to the Ventana Overlook subdivision not far south of the intersection of Kolb Road with Territory Road, in a roadcut along Territory Drive opposite the entrance to a townhouse complex near the common junction of sections 13-18-19-24, in roadcuts along the Catalina Highway and Houghton Road near their intersection, and in roadcuts along Mount Pleasant Drive and local side streets on Mount Pleasant west of the intersection of Catalina Highway with Houghton Road.

Previous Mapping: The Swan-Craycroft gravels (**Tsc**) were mapped as "upper" Rillito Formation by Voelger (1953), mostly as Rillito III (together with locally overlying "Q_j", Jaynes terrace deposits) but locally as Rillito II by Pashley (1966), as Tinaja Beds ("Ts") by Davidson (1973) and Anderson (1987), and as "QTg-QTgc-QTgf" (gravels equivalent to the Tinaja Beds and/or the Fort Lowell Formation) by Banks (1976), and were shown mostly as Unit T (exhumed basin fill), but partly as Unit M (inactive alluvial fans and terrace deposits) by Pearthree et al. (1988).

Late Oligocene – Early Miocene Pantano Formation

Indurated redbeds of the Pantano Formation (**Tpa**) are overlain unconformably by all the younger sedimentary assemblages of the Catalina foothills, with the exception of the Pima Canyon (**Qpc**) and Ventana Benchlands (**QTvb**) fan complexes, which are in contact only with units younger than the Pantano Formation. Exposures of the Pantano Formation occur both southwest and northeast of the Finisterra fault, within areas here designated as

the Pontatoc and Sabino domains, respectively. In both domains, strata of the Pantano Formation are locally in contact with mylonitic bedrock of the Santa Catalina Mountains along segments of the Catalina detachment fault. The depositional base of the Pantano Formation is nowhere exposed within the Catalina foothills.

Conglomerates of the Pantano Formation (**Tpa**) are dominantly pebble or cobble conglomerate, although boulder conglomerate is present sparingly. Clast types include: (a) abundant volcanic rocks of mainly Laramide (Cretaceous-Paleocene) aspect and metasedimentary rocks (hornfels-semischist-schist) of dominantly Precambrian age, derived from Pinal Schist and metamorphosed Apache Group; (b) subordinate granitic and aplitic rocks derived from the Middle Proterozoic Oracle-Ruin suite (Dickinson, 1991, p. 12, Table 1) and quartzite clasts derived from Precambrian and/or Paleozoic sedimentary units; (c) minor clasts derived from Precambrian diabase and Paleozoic limestone; and (d) rare clasts of mylonitic gneiss that were probably derived from basement affected by Laramide (rather than mid-Tertiary) deformation. The clast assemblage implies deposition of the Pantano Formation prior to exposure of mylonitic gneiss now forming the adjacent forerange of the Santa Catalina Mountains. Prevalent paleocurrents nevertheless generally reflect sediment transport toward the southwest, perhaps off fault scarps that existed during tectonic denudation of the Catalina core complex by displacements along the bounding detachment system. Pantano deposition evidently occurred, however, within supra-detachment basins that tapped bedrock sources lying exclusively within the upper plate of the detachment system.

Indirect arguments suggest that strata of the Pantano Formation in the Catalina foothills are equivalent to the upper part (<25 Ma) of the type Pantano Formation in Cienega Gap to the southeast. No volcanic strata equivalent to the lava present near the middle of the formation in Cienega Gap are present within the Catalina foothills, but analogous volcanic rock occurs at the base of the Pantano succession exposed in the intervening Rincon foothills (Drewes, 1977). These outcrops of Pantano volcanic rock of "Turkey Track porphyry" type at Twin Hills in east Tucson lie only 4 km south of the mapped area. The volcanic rocks may not be continuous or of the same age laterally, and may conceivably have overlapped older Pantano strata to rest directly on basement rocks only locally at Twin Hills. It seems unlikely, however, that no volcanic rocks would be exposed in the Catalina foothills if equivalent stratigraphic horizons were present, and more likely that volcanic rocks analogous to the Twin Hills exposures do not occur within the Catalina foothills simply because the local base of the formation is not exposed. As the upper part of the Pantano Formation above intercalated lava is approximately 750 m thick in Cienega Gap, all the exposures in the Catalina foothills could well represent laterally equivalent strata younger that the interbedded lava present in the type locality.

Diverse dips (typically at 12°-30°) and numerous cross-cutting minor faults show that the Pantano Formation was complexly deformed during detachment faulting, with multiple tiltblocks inclined in various directions (see also Pashley, 1966). A typical array of closely spaced minor faults is well displayed in roadcuts within the Foothills II gated community between the northern ends of Campbell Avenue and Alvernon Way not

far southwest of the parking area for the Finger Rock Trail (western map plat). No attempt was made during this study to establish the stratigraphic order of Pantano exposures present internally within either the Pontatoc or the Sabino domains, nor were stratigraphic relationships between Pantano strata exposed within the two domains addressed. The sense of displacement across the Finisterra fault (down to the southwest) suggests that Pantano strata of the Pontatoc domain southwest of the fault are at least in part younger than Pantano strata of the Sabino domain northeast of the fault.

Pantano strata of the Sabino domain are dominantly streamflood deposits characteristic of alluvial fans and fluvial braidplains (Dickinson, 1991, p. 50-52). Sandy conglomerate and conglomeratic sandstone are interbedded in varying proportions, along with horizontally laminated sandstone indicative of deposition beneath shallow but swift currents giving rise to bedforms of the upper flow regime. By contrast, Pantano strata of the Pontatoc domain include abundant matrix-rich debris-flow deposits, together with varying proportions of streamflood deposits, and also clay-rich lakebeds, with local bedded gypsum occurrences, suggestive of bolson deposition in playa settings flanked by steep alluvial fans. Analogy with strata of the upper Pantano Formation in Cienega Gap (Finnell, 1970; Balcer, 1984) suggests that the Sabino domain may represent fluvial deposits which graded upward into lacustrine and associated deposits of the Pontatoc domain, although laterally correlative strata may be present to some extent within the two domains. The closed drainage basin or basins in which lacustrine strata were deposited presumably reflected structural disruption of the upper plate of the Catalina detachment system by supra-detachment normal faults that splayed off the master detachment fault.

Outcrops: Within the Pontatoc domain (western map plat), informative outcrops of the Pantano Formation (**Tpa**) are readily accessible in roadcuts along Skyline Drive between Alvernon Way and Swan Road, in roadcuts along Hacienda del Sol Road near its intersection with Sunrise Drive, and in natural cutbanks along Pontatoc Wash between Skyline and Sunrise Drives, with the latter exposures traversible on foot from a small parking area beside Pontatoc Road at the crossing of the first small wash south of Skyline Drive. Lacustrine beds are best displayed in Section 4 along the middle reach of the stream valley lying southeast of Table Mountain Road. Within the Sabino domain (mostly eastern map plat), the most informative outcrops of the Pantano Formation (**Tpa**) occur in vertical cuts at the entrance to a townhouse complex ("The Ridge at Ventana Canyon") off Kolb Road just west of the Whaleback (a monolithic outcrop located on the golf course of the Ventana Inn near the east edge of the western map plat), in roadcuts along the Catalina Highway just northeast of its intersection with Houghton Road, and in a roadcut along the north side of Redington Road just east of its intersection with Soldier Trail.

Previous Mapping: The Pantano Formation (**Tpa**) was mapped as "lower" and "middle" Rillito formation by Voelger (1953), as Rillito I and Rillito II by Pashley (1966), as both "Tos" (=Pantano Formation) and "Ts" (=Tinaja Beds) by Davidson (1973) and Anderson (1987), and as "Tog" (older gravel) by Banks (1976), and was shown by Pearthree et al. (1988) as "pre-bf" (pre-basin fill) substratum within the Sabino domain, but was not shown separately from overlying deposits of Unit M (inactive alluvial fans

and terrace deposits) within the Pontatoc domain.

Mesozoic (Cretaceous)Bisbee Group

Complexly deformed Cretaceous redbeds of the Bisbee Group (**Kbi**) are exposed directly above the Catalina detachment fault, and cut by supra-detachment normal faults, near the eastern edge of the mapped area. Sandstones of the Bisbee Group are quartz-rich, unlike the lithic sandstones of the Pantano Formation (**Tpa**), and intercalated mudstone and siltstone closely resemble Bisbee redbeds exposed elsewhere in multiple mountain ranges of southeastern Arizona. The absence of conglomeratic strata provides a distinctive lithologic contrast with Tertiary redbeds of the Pantano Formation (**Tpa**), which contains some conglomerate in all exposures of any appreciable extent. Outcrops of Bisbee Group (**Kbi**) east of Rinconado Road and near Deep Well Ranch are on private property that is not open to public entry without permission, but outcrops in roadcuts along Wentworth Road are readily accessible to public view. The normal fault near Wentworth Road placing Bisbee Group (**Kbi**) against the Pantano Formation (**Tpa**) is unexposed beneath tablelands capped by surficial sediment cover that largely masks the older units. A narrow fault sliver of fractured but otherwise undeformed Precambrian granite (**Yor**) in the upper plate of the Catalina detachment system locally intervenes between exposures of the Bisbee Group and bedrock forming the lower plate of the Catalina detachment system.

Exposures of the Bisbee Group (**Kbi**) were mapped as Rillito I (equivalent to the Pantano Formation) by Pashley (1966), as "Tos" (=Pantano Formation) by both Davidson (1973) and Anderson (1987), and as "Ts" (redbed Tertiary? sedimentary rocks) by Creasey and Theodore (1975). The history of the stratigraphic nomenclature applied to the Bisbee outcrops is discussed more fully in the previous section on stratigraphic nomenclature.

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MAP LEGEND

A. Line Symbols

erosional escarpment along edge of Rillito alluvial flats

depositional contact (dotted line denotes base of overlying unit)

topographic discontinuity between selected pediment/terrace levels

high-angle normal fault (ball symbol on hanging wall)

low-angle normal fault (double ticks on upper plate)

fault trace concealed by overlapping sedimentary units

30 — dip of inclined fault surface in degrees

20 20 — strike and dip (degrees) of bedding in stratified units

⊕ — horizontal bedding (dip <1.5°)

B. Holocene Alluvium

Qal modern and submodern alluvium along major stream valleys

C. Pleistocene (Younger) Piedmont Gravel Units

Qss Snyder-Soldier fan complex

Qfr Finger Rock fan complex

Qpc Pima Canyon fan complex

D. Pliocene(?)-Pleistocene Piedmont Gravel Units

QTdw Deep Well Ranch bench-gravel complex

QTca Campbell Avenue fan complex

QTvb Ventana Benchlands fan complex

E. Miocene and Older Map Units

Tsc	Swan-Craycroft gravels (Miocene?)
Tpa	Pantano Formation (Oligocene-Miocene)
Kbi	Bisbee Group (Cretaceous)
bcc	bedrock of Catalina core complex
Yor	Oracle-Ruin granite suite (Middle Proterozoic)

Table 1. Previous Designations of Map Units

this work	Voelger 1953	Pashley 1966	Davidson 1973	Banks 1976	Anderson 1987	Pearthree et al 1988[1]
Qal	-	Qal	Qs_3	Qal	Qf	Y
Qss	alluvial fans	Q_j	Qs_2	Qs	-	M
Qfr	alluvial fans	Q_j	Qs_2	Qtg	-	M
Qpc	alluvial fans	QTb-QTbc	Qs	Qtg	Qf	M>T
QTdw	-	Q_c	Qs_1	-	-	O
QTca	alluvial fans	QTb-QTbc	Qs	QTg	Qf	T>M
QTvb	alluvial fans	QTb	Qs	QTg	-	T
Tsc	upper Rillito	Tr_{II} & Tr_{III}	Ts[2]	QTg	Ts[2]	T>M
Tpa	lower to mid Rillito	Tr_I & Tr_{II}	Ts[2] & Tos[3]	Tog	Ts[2] & Tos[3]	pre-bf
Kbi	-	Tr_I	Tos[3]	Ts[4]	Tos[3]	pre-bf

[1] Unit designations generally compatible with detailed mapping by McKittrick (1988) and Jackson (1989)
[2] Tinaja (Tinaga) Beds [3] Pantano Formation [4] Creasey and Theodore (1975) [not in Banks map area]

Table 2. Summary of post-mid-Tertiary Sedimentary, Structural, and Geomorphic Evolution of Catalina Foothills Piedmont Belt

(timing of events inferred without local fossil or radiometric data)

A. Oligocene to Miocene:

Deposition and faulting-tilting of indurated nonmarine redbeds (debris-flow, streamflood, and lacustrine deposits) of Pantano Formation (**Tpa**) in fault-controlled supra-detachment basin(s) atop a substratum of pre-Tertiary rocks forming disrupted upper plate of Catalina detachment fault (sediment sources lying exclusively within upper plate of Catalina detachment system)

B. Intra-Miocene:

(1) Deposition of Swan-Craycroft gravels (**Tsc**) as piedmont alluvial fan complex derived dominantly from sources within tectonically denuded lower plate of detachment system, with local recycling of clasts in underlying Pantano Formation derived originally from upper plate

(2) Offset of Swan-Craycroft gravels (**Tsc**), and subjacent Pantano Formation (**Tpa**), across Finisterra splay fault (off Catalina detachment fault) cutting upper plate of detachment system

C. Pliocene: initial erosional development of Catalina foothills piedmont ramp (uncertain timing)

D. Pliocene to Pleistocene:

(1) Development of Craycroft pediment surface across deformed Swan-Craycroft gravels (**Tsc**); coeval deposition of ancestral Ventana-Sabino alluvial fan deposits as Ventana Benchlands fan complex (**QTvb**) built across Finisterra fault trace prior to development of Finisterra escarpment

(2) Erosional development of antithetic Finisterra fault-line escarpment with progressive stream captures involving upper and lower courses of piedmont streams (Ventana-Sabino-Bear Creeks) crossing Finisterra fault trace; incision of Swan pediment surface into Swan-Craycroft gravels (**Tsc**) west of Craycroft pediment surface and coeval deposition of Campbell Avenue fan complex (**QTca**) along mountain front west of juncture of Finisterra fault with Catalina detachment fault

(3) Formation of local pediment surface, veneered by Deep Well Ranch bench-gravel complex (**QTdw**), across eroded structures of Catalina detachment system east of Agua Caliente Wash

D. Pleistocene:

(1) Deep dissection and partial removal of Ventana Benchlands (**QTvb**) and Campbell Avenue (**QTca**) fan complexes, partly in response to clipping of toe of composite Catalina foothills piedmont ramp (alluvial fans and pediments) by lateral erosion of migratory Rillito River

(2) Deposition of Pima Canyon (**Qpc**) and Finger Rock (**Qfr**) fan complexes inset below remnant surface of Campbell Avenue fan complex (**QTca**), and of compound Snyder-Soldier fan complex (**Qpc**) along mountain front east of juncture of Finisterra fault with Catalina detachment fault

E. Holocene:

Deposition of alluvium (**Qal**) along master streams (Rillito River, Tanque Verde Wash, and major tributaries) and intricate dissection of composite Catalina piedmont ramp composed of multiple remnant alluvial fans and pediments of widely varying ages, as outlined above in table