TERTIARY SEDIMENTARY ROCKS AND STRUCTURES OF THE CIENEGA GAP AREA, PIMA COUNTY, ARIZONA

By

Daniel J. Brennan

ABSTRACT

The Cienega Gap area lies about 30 miles southeast of Tucson, Pima County, Arizona, in the pass between the San Pedro and Santa Cruz River valleys to the east and west and the Rincon and Empire Mountains to the north and south.

The area includes igneous, metamorphic, and sedimentary rocks ranging in age from Precambrian to Recent. Pre-Tertiary rocks comprise Cambrian, Pennsylvanian, Permian, and Cretaceous(?) formations and intrusive bodies of Precambrian, pre-Cretaceous, and Cretaceous-Tertiary(?) age. Tertiary and younger rocks include the Pantano Formation of Miocene(?) age and younger alluvial deposits. Two metamorphic units, Cretaceous-Tertiary gneiss and schist and Tertiary(?) limestone conglomerate, occur in the area.

The Pantano Formation is a thick sequence of continental deposits ranging from boulder conglomerate to mudstone. The type section of the Pantano, disregarding the effects of faults and the discontinuity of exposures, measured 13,762 feet thick. The top and the bottom of the formation are everywhere covered; no repetition of beds by faulting was recognized; the maximum thickness of the formation is not known. Sedimentary evidence precludes an explanation of the thickness of the unit by foreset bedding.

The age of the Pantano Formation is considered to be at least in part Miocene(?), based on similarities with the Mineta Formation.

The types of sediments in the Pantano Formation and the measured thickness suggest that the unit was deposited in a subsiding continental basin in an area of relatively high but varying relief. The presence of highlands and basins suggests that basin-and-range type of structure began to form in southern Arizona during early Miocene time.

The Pantano Formation generally dips east and forms the base of a series of thrust blocks of older rocks ranging in age from Precambrian to Cretaceous-Tertiary(?). The thrusting is tentatively considered to be of Miocene(?) age.

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INTRODUCTION

The Cienega Gap area lies about 30 miles southeast of Tucson, Pima County, Arizona (fig. 1.1), in the pass between the Santa Cruz and San Pedro River valleys. The area generally covers the west slopes of the pass between the 4,000-foot contour along the Rincon Mountains to the north and the Empire Mountains to the south. This report defines the Pantano Formation, a sequence of continental deposits of probable middle Tertiary age, and discusses the relationships of the Pantano Formation to the other rocks of the area.

The total relief in the Cienega Gap area is about 1,000 feet, ranging in altitude from about 3,000 feet on the west side to about 4,000 feet along the fronts of the Rincon and Empire Mountains. The area is a moderately dissected westward-sloping plain whose surface is composed of late Cenozoic alluvial deposits and older consolidated rocks.

Little published information on the area is available. The area south of Pantano is shown as "Quaternary gravels and sands" by Schrader (1915), and an unpublished open-file report by Moore, Tolman, Butler, and Hernon (1941) briefly discussed the area north of Pantano. The geology of the Empire Mountains, south of the Cienega Gap area, has been the subject of many unpublished detailed reports.

The writer gratefully acknowledges the aid of many persons in the completion of this study, originally made for a dissertation completed at the University of Arizona (Brennan, 1957). Professors John F. Lance, Willard C. Lacy, and Robert L. DuBois of the Department of Geology assisted in various phases of the report, and Dr. Frederic W. Galbraith made available his manuscript map of the Empire Mountains. Messrs. Annan Cook of the Bear Creek Mining Co., L. A. Heindl of the Geological Survey, and Donald Layton spent time in the field with the author.

GENERAL GEOLOGY

Rocks in the area range in age from Precambrian to Recent and include

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igneous, metamorphic, and sedimentary rocks (fig. 4.1). Sedimentary rocks present in the area are composed of parts of the Cambrian Bolsa Quartzite, undifferentiated Pennsylvanian and Permian formations, Cretaceous Bisbee(?) Formation, Miocene(?) Pantano Formation, late Tertiary fanglomerate and stream deposits, and Quaternary alluvium. Parts of the Cambrian rocks and the Devonian and Mississippian formations reported in the Empire and Rincon Mountains are missing in the area, probably due to faulting.

Igneous rocks ranging in age from Precambrian to lower Miocene(?) are present. Intrusive bodies include Precambrian granodiorite, pre-Cretaceous granite, and Cretaceous-Tertiary(?) quartz monzonite. Extrusive rocks include salic rocks in the Bisbee(?) Formation and andesite in the Miocene(?) Pantano Formation. Two metamorphic units are recognized: Cretaceous-Tertiary(?) gneiss and schist and Tertiary(?) limestone conglomerate.

The pre-Tertiary rocks are thrust into the area and the tilted Pantano Formation is the base upon which all other units rest. Post-Pantano deposits are not disturbed.

Only the Tertiary sedimentary rocks in the Cienega Gap area are described in this report, and the areal relationships of all units are shown in figure 4.1. The structural relationships are discussed briefly and are shown diagrammatically on the cross section in figure 4.2.

PANTANO FORMATION

The name Pantano Formation has long been used informally by geologists in this region to describe a group of maroon-colored continental deposits in the vicinity of Tucson. C. F. Tolman first used the name in an unpublished manuscript and the name was adopted in an open-file report of the Geological Survey (Moore, et al., 1941). The Pantano Formation is here defined and described.

The Pantano Formation is a sequence of continental deposits ranging from boulder conglomerate to mudstone that crops out extensively in the Cienega Gap area and is named for the railroad station, Pantano, in whose vicinity it is well exposed. Voelger (1953), in an unpublished report, describes similar rocks north and east of Tucson under the name Rillito Formation, but this name is rejected in favor of the older and better known unpublished name, Pantano. The type section of the Pantano Formation detailed below is located in discontinuous exposures along about 5 miles of U.S. Highway 80 starting about 1.7 miles east of Mountain View (fig. 4.1).

Type section (partial), Pantano Formation, measured along south side of U.S. Highway 80 between about the east line of sec. 2, T. 17 S., R. 17 E., and the center of the W-1/2 sec. 31, T. 16 S., R. 17 E. (between Arizona Highway Department survey coordinates 1,233 + 00 and 1,458 + 00).

Quaternary:	Thickness (in feet)
Alluvium:	
Light-brown sandstone and conglomerate.	

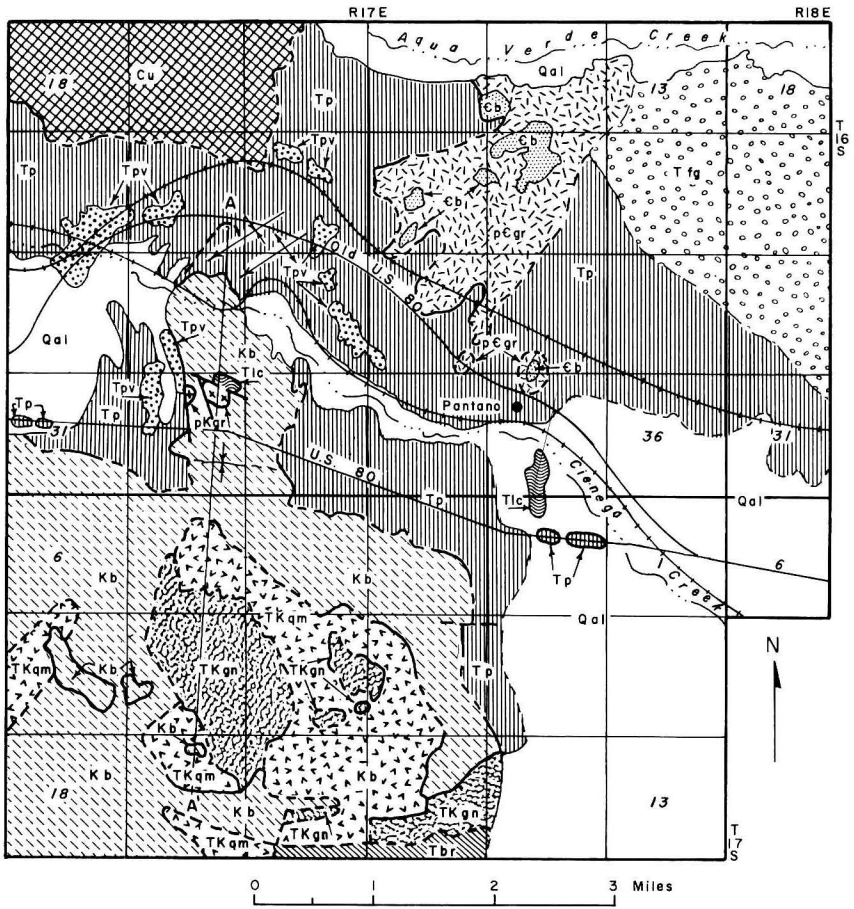

Figure 4.1.--Generalized geologic map of the Cienega Gap area, Pima County, Ariz.

EXPLANATION

SEDIMENTARY ROCKS

Pleistocene and Recent	Qal	Alluvium
Late Tertiary	Tfg	Fanglomerate
Miocene(?)	Tp / Tpv	Pantano Formation with interbedded volcanic rocks
Lower Cretaceous	Kb	Bisbee Formation
Carboniferous	Cu	Undifferentiated rocks
Cambrian	Cb	Bolsa Formation

IGNEOUS ROCKS

Tertiary-Cretaceous	TKqm	Quartz monzonite
Pre-Cretaceous	pKgr	Granite
Precambrian	pCgr	Granodiorite

METAMORPHIC ROCKS

Tertiary	Tbr	Quartzite-Quartz monzonite breccia
	Tlc	Limestone conglomerate
Tertiary-Cretaceous	TKgn	Gneiss

Contact — dashed where inferred

Fault — dashed where inferred

Folds showing direction of plunge

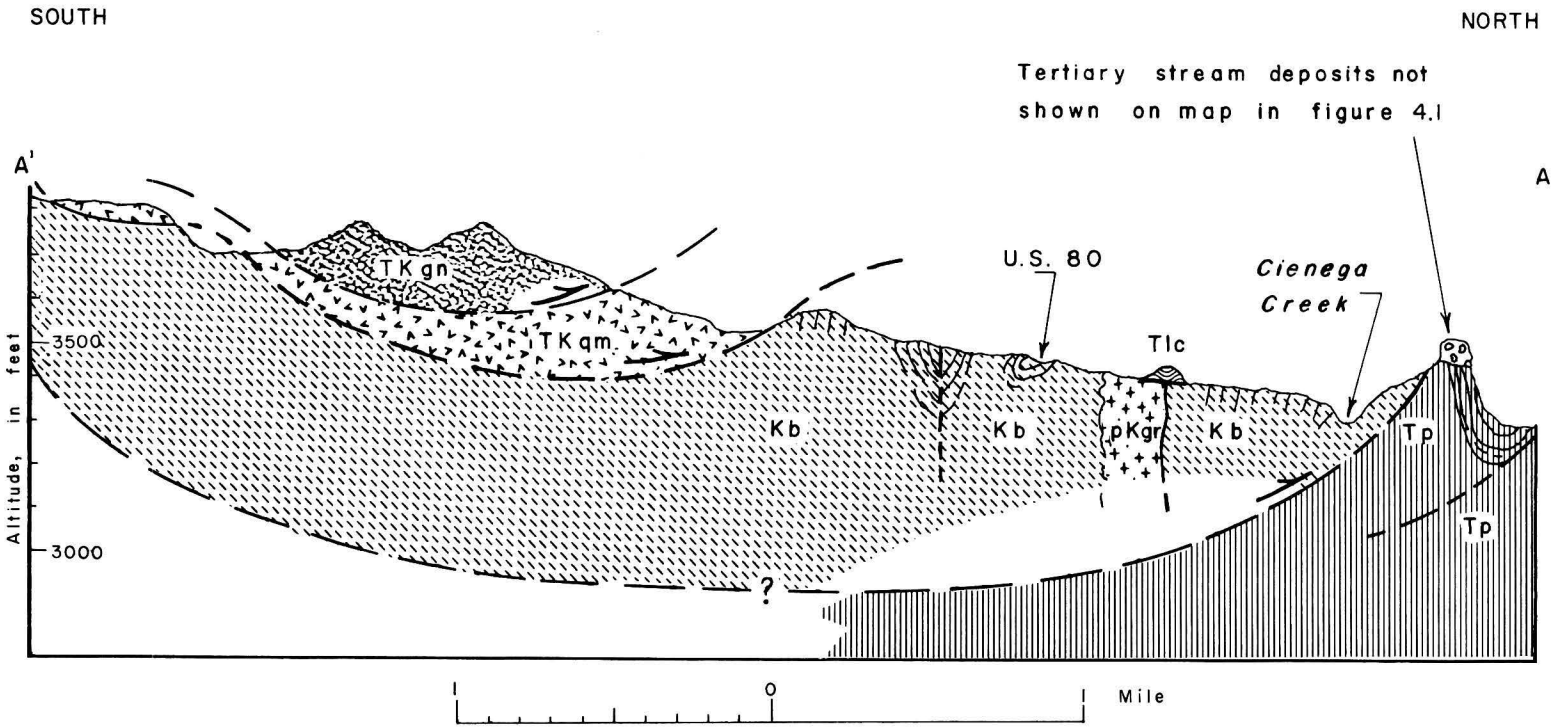

Figure 4. 2. --Geologic sketch along section A-A', Cienega Gap area, Pima County, Ariz. (For location of section, see fig. 4. 1.)

Angular unconformity.

Thickness (in feet)

Tertiary:

Pantano Formation (beds strike generally north-south and dip between about 14° to about 55° to the east):

1. Sandstone and mudstone: light green and pale maroon; fairly well sorted; alternating beds up to 10 inches thick; calcareous 352

2. Limestone: white; argillaceous; unit composed of two beds of limestone about 6 inches thick separated by 1 foot of gray mudstone 2

3. Mudstone: pinkish gray; well bedded 87

4. Sandstone, conglomerate, and mudstone: gray; alternating beds of very coarse grained sandstone to pebble conglomerate; composed mostly of quartzite and sandstone fragments with minor amounts of volcanic rocks and, in the lower half, a few jasper pebbles; conglomerate predominates in the lower portion of the unit which becomes finer upward and grades into the overlying mudstone 645

5. Covered interval 565

6. Sandstone and pebble conglomerate: light brown; contains few boulders up to 16 inches in diameter and some mudstone; composed mostly of quartzite, limestone, and volcanic rock fragments; soft, poorly exposed 180

7. Conglomerate: red brown; massive; boulders up to 18 inches in diameter; composed of arkose, sandstone, limestone, and volcanic rocks 214

8. Fault: N. 30° W., 45° NE.; probably normal; undetermined displacement.

9. Mudstone, sandstone, and pebble conglomerate: sandstone and conglomerate, brown; sandy mudstone, red, with increasing amounts of green color toward top; sandstone and conglomerate well cemented and very hard, mudstone soft; few boulders up to 8 inches in diameter; mudstone tuffaceous at base and increasingly so upward, with tuff beds intercalated with sandstone at top 364

10. Conglomerate: sandy; contains arkose and volcanic rock fragments; limestone fragments absent 171

11. Sandstone: grayish brown; with 6-inch thick pebble lenses and lenses of red-brown sandy mudstone 141

12. Conglomerate: grayish brown; mostly beds of pebbles with layers of boulders up to 36 inches in diameter; few sand lenses; composed of volcanic rocks, quartzite, arkose,

		Thickness (in feet)
	black thin-bedded limestone and soft green sandstone fragments	167
13.	Covered interval	540
14.	Sandy conglomerate: red brown; with boulders up to 48 inches in diameter; composed of volcanic rocks, quartzite, arkose, thin-bedded limestone; cobbles common toward the top	458
15.	Covered interval	115
16.	Conglomerate: red brown; boulders up to 12 inches; composed of volcanic rocks, quartzite, arkose; limestone absent	43
17.	Fault: N. 25° E., 60° NW.; undetermined displacement.	
18.	Sandstone: green gray; tuffaceous; thin boulder layers	20
19.	Fault: N. 20° W., dips up to 20° NE.; undetermined displacement.	
20.	Conglomerate: red; boulders of quartzite, arkose, limestone, and volcanic rocks up to 8 inches in diameter; contains sandy lenses	175
21.	Fault: N. 20° E., 50° NW.; probably normal; unknown offset.	
22.	Sandy pebble conglomerate: fragments up to 8 inches in diameter but predominantly less than 1 inch; composed of quartzite, arkose, and volcanic rock fragments with rare limestone fragments; contains three lenses of green tuffaceous sandstone and lenses of red mudstone near top	126
23.	Covered interval	126
24.	Sandstone: gray; pebbly	45
25.	Covered interval	61
26.	Andesite flow: maroon; porphyritic	6
27.	Covered interval	75
28.	Pebbly conglomerate: angular to rounded; pebbles predominant; composed of maroon quartzite, limestone, sandstone, and volcanic rocks; poorly bedded	25
29.	Fault: N. 15° W., 40° SW.; undetermined offset;	

		Thickness (in feet)
	unknown displacement.	
30.	Sandstone and mudstone: pale reddish brown; pebbly; beds up to 6 inches thick; composed of arkose, quartzite, and volcanic rock fragments; cut by many small faults	92
31.	Fault: N. 15° E., vertical; unknown displacement.	
32.	Andesite flow: maroon; porphyritic	5
33.	Conglomerate: deep red; contains boulders and cobbles of quartzite and volcanic rocks	31
34.	Fault: N. 15° E., vertical; unknown displacement.	
35.	Conglomerate: red at base, losing color toward top; angular to rounded, with boulders up to 30 inches in diameter; composed of light- and dark-colored volcanic rocks and arkose, quartzite, and some limestone and soft sandstone boulders; some sandy beds	58
36.	Covered interval	133
37.	Conglomerate: red; becomes coarser toward top with boulders up to 48 inches in diameter; massive; crudely bedded; contains light-colored volcanic rocks, quartzite, and black limestone fragments; cut by faults	328
38.	Covered interval	91
39.	Conglomerate: red; pebbles to boulders up to 28 inches in diameter; angular to rounded; composed of acid volcanic rocks and quartzite fragments with black dense limestone appearing toward top	530
40.	Covered interval	372
41.	Conglomerate: brown at base, increasingly red toward top; fragments up to 8 inches in diameter, coarsening toward top with 24-inch boulders of green quartzite; composed of granite, quartzite, arkose, two types of andesite, and sparse limestone	838
42.	Conglomerate: brown; contains up to 6-inch cobbles and some sand lenses; composed of limestone, sandstone, quartzite, arkose, and acid volcanic rocks	19
43.	Covered interval	356
44.	Sandy, pebbly conglomerate: beds up to 18 inches thick; sandstone beds decrease upward with only few lenses at top	423

		Thickness (in feet)
45.	Fault: N. 30° W., 70°; normal; offset unknown.	
46.	Mudstone, sandstone, and pebble conglomerate: gray and maroon sandstone, maroon pebble conglomerate, and light-gray-maroon mudstone; coarser at the base and at top, with mudstone in middle; pebbles of quartzite, arkose, limestone, and mudstone; folded and faulted on north side of highway with only a small fault apparent on the south side	346
47.	Covered interval	43
48.	Sandstone: gray and maroon; with pebble lenses	164
49.	Covered interval	33
50.	Sandy conglomerate: gray; contains lenses of gray pebble conglomeratic sandstone; thin beds of sandstone at base	117
51.	Sandstone and pebble conglomerate: dark maroon; alternating beds up to 6 inches thick; contains fragments of quartzite, mudstone, limestone, and arkose	12
52.	Fault: N. 20° E., 80° SE.; undetermined displacement.	
53.	Conglomerate: green gray; sandy and pebbly	12
54.	Covered interval	25
55.	Mudstone: maroon; conglomeratic; weathered	20
	Fault here brings in Cretaceous rocks in a thrust sheet for a horizontal distance of three-quarters of a mile. The thickness of the Pantano Formation probably underlying this block is not included in the total thickness.	
56.	Mudstone: green and maroon, predominantly maroon at base; decrease of sandy muds upward; near top, a few beds of fine- to medium-grained yellow sandstone	1,187
57.	Pebbly conglomerate: brown, with bands of red sandstone; contains boulders of quartzite, limestone, and arkose up to 12 inches in diameter; grades upward into unit above	215
58.	Andesite flow: maroon; porphyritic; upper surface weathered	20
59.	Conglomerate: maroon; massive boulders up to 60 inches in diameter; composed of red sandstone, limestone, light-colored volcanic and dark-green shallow intrusive rocks	260

		Thickness (in feet)
60.	Covered interval	245
61.	Conglomerate: maroon; subangular to rounded; massive; with fragments up to 36 inches in diameter; some red sandstone and many sandy lenses; composed of light-colored volcanic rocks	605
62.	Covered interval	330
63.	Conglomerate and sandstone: maroon; bouldery; poorly exposed	608
64.	Covered interval	473
65.	Mudstone: green, gray, and maroon; poorly exposed	888
66.	Covered interval	170
67.	Sandstone: gray brown; pebbly; poorly exposed	10
	Total thickness Pantano Formation measured	13,762

Quaternary alluvium.

The Pantano Formation is in general best described in terms of gradation of grain size and color. The base of the formation is not exposed within the area mapped. The lowermost beds exposed are brown and gray sandstone and mudstone, and the beds become coarser and redder upward. Above at least 3,600 feet of sediment, there is a 20-foot thick andesite flow which is followed by a thick sequence of sandstone and mudstone. These finer grained deposits grade upward into coarse conglomerate and two thin andesite flows, stratigraphically about 200 feet apart, interbedded with the sediments about midway in the measured section. Above the second thin andesite flow, gray sandy conglomerate grades upward into red boulder conglomerate, which in turn grades into greenish-gray mudstone, up to within about 2,000 feet of the top of the measured section. The uppermost beds exposed in the measured section become progressively finer grained, light gray in color, and contain a single 2-foot thick bed of white argillaceous limestone about 350 feet from the top of the section.

The type section does not contain two units exposed in the SE-1/4 sec. 19, T. 16 S., R. 17 E., about 1-1/2 miles north of the measured section. These are a crudely sorted and poorly stratified volcanic agglomerate and green and gray mudstone of probable lake-bed origin. The agglomerate, 50 to 100 feet thick, is dark brown to black and is composed of particles of tuff and lapilli. It overlies the lowest andesite present in the measured section. The lake-bed deposits, composed of siltstone and fine sandstone, are about 50 feet thick and are deposited on the andesite and agglomerate.

Most of the pebbles, cobbles, and boulders in the Pantano Formation are composed of arkose, sandstone, limestone, and volcanic rocks. Some limestone fragments contain fossils of upper Paleozoic age. Arkose, sandstone, and volcanic rock fragments similar to the Cretaceous rocks in the region

form the largest proportion of the fragments in the Pantano Formation.

The Pantano Formation in the type section dips between about 15° and 50° easterly, and both the top and bottom of the formation are covered by Quaternary alluvium. The Quaternary alluvium overlies the Pantano Formation with an angular unconformity, and the contacts of the Pantano Formation with other rocks in the area are faulted.

The thickness of the measured section of the Pantano Formation is 13,762 feet. This thickness does not include the thicknesses concealed by Quaternary alluvium at the base and the top of the section and the thickness which underlies the thrust sheet in secs. 32 and 33, T. 16 S., R. 17 E. The thrust sheet may conceal up to about 3,000 feet of Pantano sediments between units 55 and 56 of the measured section. Throughout the section, the Pantano Formation is cut by many faults, only a few of which have measurable displacements. Some displacements throw different rock types in apposition and the measured section may include the unrecognized repetition or omission of beds. The recurrence of andesite (section units 26, 32, and 58) may represent repetition within the section. However, the sequences of deposits both below and above the andesite flows are different in all three cases, and the repetition of the volcanic flows is assigned to recurrent volcanism. No evidence to prove repetition of other units was noted. In the calculation of the thickness of the type section, no allowance was made for any initial dip. The presence of many fine-grained beds suggests that the initial dip probably did not exceed a few degrees at most, and the present moderately high dip minimizes any possible considerable effect of the initial dip on the total thickness measured. The contact between thinly bedded sandstone and cobbles and boulders within individual lenses suggests the units were deposited with low initial dips and precludes the possibility that the dips can be interpreted as those of foreset beds. The covered intervals near the top of the measured section are believed to represent weakly cemented beds.

Correlation and Age

No definite correlation between the Pantano Formation and any other formation in the region can be made at this time. The lower member of the Rillito Formation defined by Voelger (1953) crops out north and east of Tucson and is lithologically similar to the Pantano Formation. On the northeast side of the Rincon Mountains, Chew (1952b and this volume) describes the Mineta beds which are lithologically similar to the Pantano Formation, contain andesite which is megascopically identical with the flows in the Pantano Formation, and which are involved in deformation prior to the deposition of the late Cenozoic alluvial deposition. For these reasons, it is believed that the Pantano Formation is the equivalent of at least part of the Mineta beds.

The possible correlation of the Pantano Formation with units other than the Mineta beds is considered unlikely. The Pantano Formation cannot be correlated with the Bisbee(?) Formation because it contains fragments of the Cretaceous Bisbee(?) rocks and is, therefore, younger. Alluvial deposits of late Cenozoic time overlie the deformed Pantano Formation and thus the Pantano Formation is older than the late Cenozoic deposits. Lithology, sedimentary structure, and similarity of deformation suggest that correlation with the Mineta beds is the only possibility at this time.

The Mineta beds are of lower Miocene age, based on vertebrate fossil evidence (Chew, 1952b; Lance in Wood, 1959; Chew, this volume). On the basis of the tentative correlation made above, the Pantano Formation is considered to be at least in part of Miocene(?) age.

TERTIARY-QUATERNARY ROCKS

Stream Deposits

Several erosional remnants are all that remain in this area of what was once probably a rather extensive deposit of stream-laid conglomerate. These deposits cap small mesas in the vicinity of sec. 29, T. 16 S., R. 17 E., and are also exposed in a road cut in sec. 31, T. 16 S., R. 17 E., near the west end of the measured section of the Pantano Formation. The fragments in these deposits range in size from fine sand to boulders up to about 18 inches in diameter and are composed of limestone, sandstone, acid volcanic rocks, gneiss, and granite. The sorting of the deposits is poor and the stratification is barely discernible. The unit is strongly cemented with calcite and its maximum observed thickness is about 20 feet.

The stream deposits rest with an angular unconformity upon the Pantano Formation and are themselves locally overlain by more recent poorly consolidated alluvial deposits. This unit does not appear to be related to the present drainage, and because of its stratigraphic position between the Pantano Formation and younger dissected alluvium it is tentatively considered to be of Tertiary-Quaternary(?) age.

Fanglomerate

A large body of fanglomerate of a composition that is unique in the area lies along the southern slopes below the Rincon Mountains in the northeast corner of the mapped area. More than 90 percent of the material in the fanglomerate is composed of gray quartz diorite or dioritic gneiss. It is weakly cemented by lime.

The fanglomerate overlies the Pantano Formation with an angular unconformity and is not overlain by more recent sediments. It is no longer receiving sediments from the Rincon Mountains to the north because its headwaters have been pirated by Aqua Verde Creek. It is deeply dissected and is tentatively assigned a late Tertiary or early Quaternary age. The relationship of the fanglomerate to the Tertiary stream deposits is not definitely known, but tentatively the fanglomerate is considered to be the younger unit.

QUATERNARY ROCKS

Alluvium

Alluvium covers large portions of nearly all the rocks in the area. Two

phases of the alluvium are recognized—an older phase which is not relatable to the present drainage, and a younger phase which is deposited along the present stream channels and forms a thin veener of rubble over underlying formations. The composition of both the older and younger phases of the alluvium is similar. They contain fragments of all older rocks in the area which range in size from clay to boulders but are predominantly conglomeratic. The fragments are subangular to subrounded and the alluvium is poorly consolidated. Near the surface it frequently contains a concentration of caliche.

These alluvial deposits rest unconformably on all the older rocks. Generally the unconformity is angular but the angularity is slight where the alluvium overlies Tertiary stream deposits.

The older phase covers large areas in the east and west portions of the area mapped but it can be definitely identified only in arroyos and road cuts. Elsewhere it cannot be distinguished from the alluvial deposits of the younger phase. The alluvial deposits of the older phase are structurally higher than those of the younger phase and have been extensively dissected.

The age of these deposits is not known. Alluvial slope deposits in the vicinity of Benson analogous to those of the older phase contain late Pleistocene vertebrate fauna (Lance, personal communication). The relationship of the alluvial deposits of the older phase to the Tertiary-Quaternary fanglomerate is not known except that both are now being dissected.

STRUCTURE

The structure of the rocks in the Cienega Gap area is complex. In general, the tilted, folded, and faulted rocks of the Pantano Formation form a base which has been overridden by a series of thrust blocks. Faulting and folding within the thrust blocks further complicate the structural relationships. Many of the faults may be resolved into components of a major compression from the southeast, but others appear to be random.

The Pantano Formation is generally tilted to the east, with dips ranging between about 15° to 50°. Local shallow folds, such as those in the vicinity of the northwest corner of sec. 28, T. 16 S., R. 17 E., trend northeast. The Pantano Formation is cut by a multitude of faults of varying magnitude which show no preferred orientation.

At least five thrust blocks, or groups of thrust blocks, rest upon the Pantano Formation in the Cienega Gap area. Along the north edge of the area there are two thrust blocks exposed. To the east there is a block of Precambrian granodiorite topped by Cambrian Bolsa Quartzite, and to the west there is a large area of undifferentiated upper Paleozoic rocks. The block containing the granodiorite and Bolsa Quartzite is almost free of faults; in contrast, the block containing the Paleozoic sedimentary rocks is extensively faulted and folded (Layton, personal communication). The largest single thrust block lies in the central portion of the area. It is composed of folded and faulted Bisbee(?) rocks in which the folds trend essentially east-west. The best developed sets of faulting within this block trend north-south and east-west. The block of Bisbee(?) rocks is overridden by a thrust block of Late Cretaceous-Tertiary(?) quartz monzonite which in turn is overthrust in part by a thrust block of Late Cretaceous-Tertiary(?) schist and gneiss.

These relationships are shown graphically in figure 4.2 and are interpreted as follows: The northeast-striking folds in the Pantano Formation were possibly formed in response to the pressure of the overriding block of the Bisbee(?) Formation. The trend of these folds would most probably be normal to the direction of the encroachment of the thrust block, and therefore it is suggested that the compressive stress was from the southeast. The north-south and east-west sets of faults within the Bisbee(?) rocks possibly represent lines of shearing at approximately 45° to this direction. The folds within the Bisbee(?) Formation, in contrast, trend east-west, suggesting that the blocks of Bisbee(?) rocks were either rotated during the thrusting or that the direction of stress changed between the time the Bisbee(?) Formation was folded and the time it was thrust over the Pantano Formation. During the thrusting, individual shear blocks of the Bisbee(?) Formation moved past one another in irregular fashion, resulting in the complicated section of Bisbee(?) rocks now present in the area.

The thrusting involves the Pantano Formation of lower Miocene(?) age and does not affect alluvial rocks of possible late Tertiary age. Therefore, this period of intense crustal compression is considered to be post-lower Miocene(?) and pre-late Tertiary, or Miocene(?).

SUMMARY

The Pantano Formation consisting predominantly of continental clastic sediments of probable lower Miocene age is defined and described. The Pantano Formation consists of at least 13,762 feet of conglomerate, sandstone, and mudstone with three andesite flows intercalated with the sediments. Its base is not exposed and the formation is overlain unconformably by late Tertiary and Quaternary alluvial deposits. The types of sediments in the Pantano Formation and the measured thickness suggest that the unit was deposited in a subsiding continental basin in an area of relatively high but varying relief. The presence of highlands and basins suggests that basin-and-range type of structure began to form in southern Arizona during early Miocene time.

The Pantano Formation generally dips to the east and forms the base of a series of thrust blocks of older rocks ranging in age from Precambrian to Late Cretaceous-Tertiary(?). The largest thrust block is the central part of the area and consists of three imbricate blocks. The lowest of these is formed of Cretaceous Bisbee(?) rocks which are folded and faulted and thrust onto the Pantano Formation. Above the Bisbee(?) rocks are successive thrust blocks of Late Cretaceous-Tertiary(?) quartz monzonite and Late Cretaceous-Tertiary(?) gneiss and schist.

Folding in the Pantano Formation and fault sets in the Bisbee(?) rocks suggest compression from the southeast. The thrusting is younger than the Pantano Formation and is tentatively considered to be of Miocene(?) age.

Late Tertiary and Quaternary alluvial deposits were laid down in the area following the faulting and are now being dissected.