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THE MINETA FORMATION, A MIDDLE TERTIARY UNIT IN SOUTHEASTERN ARIZONA

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ABSTRACT

The Mineta Formation, a sequence of continental deposits on the east side of the Rincon Mountains, Pima County, Arizona, contains the first datable middle Tertiary fossils in southeastern Arizona. The rocks included in the Mineta Formation heretofore had been considered to be younger than Cretaceous and older than upper Pliocene on the basis of geologic relationships alone.

The Mineta Formation comprises conglomerate, sandstone, mudstone, and limestone deposits separated into three units. Although they are separated by faults, the three units are considered to be part of a single formation because of compositional and textural similarities. Andesite porphyry with large tabular plagioclase phenocrysts intrudes and possibly forms flows on the Mineta.

The middle Tertiary age of the Mineta Formation is based on fragmentary remains of a rhinoceros of probable early Miocene age located in the middle of the upper unit.

The middle Tertiary age of the Mineta Formation also demonstrates locally, and suggests regionally, the existence of post-Cretaceous and pre-upper Tertiary deformation, erosion, and deposition. The structural relationships of the Mineta Formation to Cretaceous(?) and Precambrian(?) rocks demonstrate post-early Miocene and pre-upper Pliocene thrusting.

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INTRODUCTION

This paper describes the Mineta Formation, the sequence of continental deposits from which were collected the first datable middle Tertiary fossils in southeastern Arizona (Chew, 1952a; 1952b). The rocks included in the Mineta Formation compose one of the many areas of deformed continental deposits that heretofore have been considered to be younger than Cretaceous and older than upper Pliocene on the basis of geologic relationships alone. The wide distribution, considerable local thicknesses, intense structural involvement, and lack of datable fossils from these deposits have led to considerable speculation regarding their place and significance in the geologic history of the region. The probable early Miocene age of the upper unit of the Mineta Formation demonstrates locally, and suggests regionally, the existence of post-Cretaceous and pre-upper Tertiary deformation, erosion, and deposition. The structural relationships of the middle Tertiary Mineta Formation demonstrate the presence of post-early Miocene and pre-late Pliocene thrusting.

The area from which the Mineta Formation is described is on the east side of the Rincon Mountains in Pima and Cochise Counties, Arizona, about 30 miles east of Tucson (fig. 1.1). The area is in the vicinity of the Bar LY Ranch and is about 5 miles long and 1 mile wide (fig. 3.1). It includes Mineta Ridge, a group of low hills which lies between the rugged uplands of the Rincon Mountains on the west and the San Pedro Valley on the east. Maximum relief is about 800 feet and altitudes range from about 3,250 to about 4,050 feet.

GEOLOGIC SETTING

The Mineta Ridge area includes pre-middle Tertiary igneous and metamorphic rocks, middle Tertiary sedimentary and middle(?) Tertiary volcanic and intrusive rocks, and late Cenozoic alluvial rocks (fig. 3.1). The middle and middle(?) Tertiary rocks, which include the Mineta Formation, are discussed in detail separately.

The pre-middle Tertiary rocks are composed predominantly of metamorphosed sedimentary and granitic rocks. The metamorphosed sediments include stretched-pebble conglomerate, contorted phyllite, and fine-grained

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1/ Department of Properties and Industrial Development, Northern Pacific Railway Co.

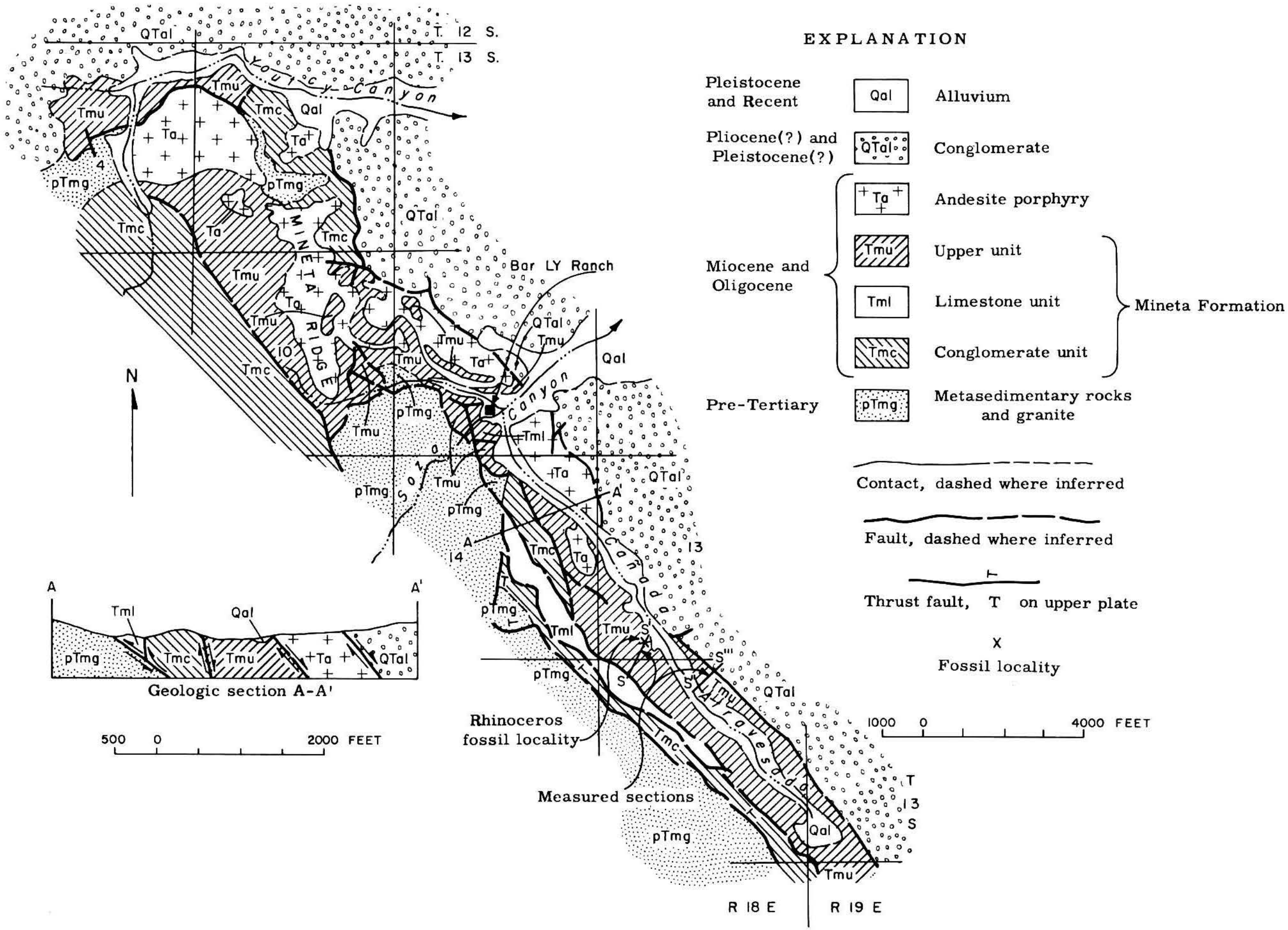

Figure 3.1—Generalized geologic map and section of the Mineta Ridge area, Pima County, Ariz.

marble. The metamorphic rocks may be of Cretaceous age (Hernon, 1932, p. 24) or they may be older. The coarse-grained granite is lithologically similar to granite exposed about 20 miles northwest which was considered to be of Precambrian age by Ludden (1950, p. 32), but its relationships to the metamorphic rocks are not known. However, the granite underlies the Mineta Formation and its fragments form a large proportion of the basal unit; thus the granite is clearly of pre-middle Tertiary age.

Rocks younger than the middle and middle(?) Tertiary rocks are composed of alluvial deposits which are in part continuous with the late Cenozoic alluvial fill of the San Pedro Valley. Portions of these late Cenozoic deposits include fragments of pre-middle Tertiary and middle(?) Tertiary rocks now exposed in Mineta Ridge and the Rincon Mountains. Elsewhere in the San Pedro Valley, alluvial deposits are known to range in age from upper Pliocene to lower Pleistocene (Gazin, 1942).

The middle and middle(?) Tertiary rocks are exposed in a series of fault blocks and slivers which lie along an extensively deformed north-northwest-trending zone between older igneous and metamorphic rocks of the Rincon Mountains and the relatively undisturbed alluvial deposits of the San Pedro Valley. The middle and middle(?) Tertiary rocks appear to have been thrust over the older granitic and metamorphic rocks to the west and to be in normal fault contact with the younger alluvial rocks to the east. The late Cenozoic alluvial rocks in this area are not involved in the thrusting and the thrusting is assumed to be pre-Pliocene, on the basis of a probable Pliocene-Pleistocene age for the alluvial fill.

MIDDLE AND MIDDLE(?) TERTIARY ROCKS

Rocks of demonstrated and probable middle Tertiary age in the area include the Mineta Formation and the younger andesite porphyry, which has a post-depositional history similar to the Mineta Formation.

Mineta Formation

Sedimentary rocks forming the unit defined as the Mineta Formation in this paper crop out in a narrow band along the length of Mineta Ridge, for which the formation is named, and are exposed continuously for more than 2 miles south of the area mapped (fig. 3.1). The topography developed on rocks of the Mineta Formation depends on the lithology of the particular rock types involved and the comparative resistance of adjacent rocks. The lower, or conglomerate, sequence of the Mineta Formation forms bold rounded cliffs and slopes where it is in contact with sandstone and mudstone; in contrast, where it is adjacent to the more resistant andesite porphyry, it forms the valleys. The middle, or limestone, sequence has been referred to in the field as the "railroad beds" because of its characteristic exposures. The thin, resistant and persistent limestone beds stand above the softer interbedded sandstone and mudstone and form conspicuous parallel "tracks" as the unit trends across successive ridges and canyons. The upper, or sandstone and mudstone, sequence forms smooth to ledge slopes and valleys.

The Mineta Formation is subdivided into three units because of lithologic differences and because the units are separated by persistent fault zones which trend approximately parallel to the bedding planes. The three units are considered to be parts of a single formation because of compositional similarities and because the lithologic differences, while striking between the conglomerate and upper two units, are consistent with the development of continental deposits laid down in a basin whose source areas are progressively lowered. The three units are the lower or conglomerate unit, the middle or limestone unit, and the upper or sandstone and mudstone unit. The conglomerate unit is definitely the lowest of the three because it is known to lie in depositional contact on the pre-middle Tertiary granite. The middle and upper units are so considered principally because of structural relationships. The top of the Mineta Formation is everywhere either faulted, in contact with andesite porphyry, or overlain disconformably by late Cenozoic alluvial deposits.

The base of the conglomerate unit lies on an erosional surface cut on granite, as exposed in the northern part of the mapped area. The amount of local relief cannot be estimated because the apparent range in the thicknesses of the conglomerate unit, from about 50 to about 1,300 feet, is to an unknown extent due to faulting. The conglomerate is arkosic and is generally reddish brown in color. The larger fragments, which range up to cobble size, are composed predominantly of granite, although granite fragments do not predominate at every locality. Limestone, quartzite, schist, and several types of fine-grained igneous rocks form smaller portions of the fragments in the conglomerate. Granite and schist, lithologically similar to fragments in the conglomerate unit, are exposed within the Mineta Ridge area and in the Rincon Mountains to the west; limestone and quartzite are known to crop out west of the Mineta Ridge area. The sources of the fine-grained igneous rocks are not known.

The conglomerate unit is composed of lenticular beds, no single one of which is known to persist for more than a few hundred feet. The unit is composed of numerous thin sand lenses interbedded with thick conglomerate lenses. The sand lenses are commonly less than 1 inch thick and rarely more than 6 inches thick; the conglomerate lenses reach a maximum of 5 feet in thickness. Bedding is well developed where alternating beds are composed of contrasting grain sizes. The total thickness of the conglomerate is not known because the upper boundaries are everywhere faulted. The greatest thickness, about 1,300 feet, is in the northern part of the area. In the southern part of the area, the conglomerate exposures range in thickness from about 50 to about 400 feet.

The middle, or limestone, unit is separated from the lower and upper unit by faults in all exposures. The unit is composed of alternating fresh-water limestone and thin siltstone and mudstone beds. The limestone beds, some of which are algal, range in thickness from about 8 to 30 inches and are characteristically marly. They are generally gray to yellowish gray on fresh and weathered surfaces, although a few fetid beds are black. The siltstone and mudstone beds form groups about 12 inches thick made up of beds about 1 inch thick.

In contrast to the noticeable lenticularity of the beds in the conglomerate unit, the thicknesses of the limestone beds and the clastic intervals between them in the middle unit are persistent. The composition of the clastic beds is feldspathic and similar to that of the finer lenses of the conglomerate unit and the clastic beds of the upper unit. The middle unit is about 50 feet thick, although locally it appears to be about 75 feet thick due to repetition by faulting.

The upper, or clastic, unit of the Mineta Formation consists predominantly of sandstone and mudstone, with smaller proportions of fresh-water limestone and fine-grained conglomerate beds. The sandstone and mudstone beds are generally purplish to medium gray, although some zones are yellow and green. The colors are in wide bands which generally parallel the bedding. The sandstone, siltstone, and fine-grained conglomerate are arkosic, and silt forms a large proportion of the matrix of the coarser grained beds. Muscovite flakes are common in the upper parts of the unit. The sediments are cemented by silica but are highly fractured and erode easily, probably because of the intense deformation in which they have been involved. The limestone beds occur most commonly in the lower portion of the clastic unit and are generally similar in appearance to the limestone beds of the middle unit. A silty gypsum bed about 15 feet thick containing a few thin mudstone layers and a tuff bed occurs in the top one-third of the upper unit. The detrital beds may be less than half an inch thick and are never more than 6 inches thick, and the limestone beds may be as much as 2 feet thick. Bedding is well developed. In general, the average grain size tends to become finer toward the top of the measured section.

The maximum thickness of the Mineta Formation is not known because of faulting, intrusion, or erosion. The partial section of the upper unit of the Mineta Formation given below was measured where the unit appears thickest. In this section the lowest beds are faulted against the middle unit, and the uppermost beds are faulted against the late Cenozoic alluvial fill. The measured section includes the limestone bed that contained the datable fossil fragments.

Partial section of the upper, or sandstone and mudstone, unit of the Mineta Formation, located in the SW-1/4 sec. 13 and the NW-1/4 sec. 24, T. 13 S., R. 18 E., Pima County, Arizona. Measured along lines S-S' and S'-S''' (fig. 3.1), using the top of the tuff bed (bed 14) as the horizon common to both lines.

	Thickness (in feet)
Late Cenozoic:	
Alluvial fill.	
Middle Tertiary:	
Mineta Formation:	
Upper unit:	
17. Mudstone and limestone: fine grained; thin bedded; locally gypsiferous	100±
16. Gypsum: silty; contains thin mudstone beds	15
15. Mudstone and limestone: fine grained; thin bedded	200±
14. Tuff: may be water laid; good marker bed	16
13. Sandstone: red; with interbedded coarse- and fine-grained layers; contains some silty limestone beds near the top	141
12. Limestone: black; fetid; resistant. The rhinoceros fossil was collected from this bed	2
11. Mudstone and limestone: red; thin bedded but bedding indistinct	37

	Thickness (in feet)
10. Mudstone: green; thin bedded and nonresistant; much local change in dip	109
9. Mudstone, siltstone, and sandstone: purple; thin bedded; contains more sand than lower units; contains mica which becomes more abundant near the top of the unit	126
8. Siltstone and sandstone: mostly green but some purple; thin limestone beds in lower 20 feet; less sandstone than in the unit below	92
7. Siltstone and sandstone: green and purple; shows good bedding with beds 1/2 to 4 inches thick	133
6. Sandstone and mudstone: purple; thin bedded; forms good outcrops; grains are poorly sorted	237
5. Mudstone and marly limestone: gray green; mudstone beds about 1 inch thick; limestone beds 1 to 1-1/2 inches thick; 1-foot limestone bed at top of unit	28
4. Marly limestone: thick bedded; lower 2-1/2 feet is clastic; contains algal remains throughout	10
3. Siltstone and mudstone: black to gray; highly contorted bedding	89
2. Limestone: light gray; massive; resistant	2
1. Siltstone and mudstone: highly contorted; marly limestone bed about 35 feet above the bottom	56
Total thickness measured, upper unit of the Mineta Formation	1,313±

Fault contact.

Middle, or limestone, unit of the Mineta Formation.

In recapitulation, the maximum thicknesses of the three units of the Mineta Formation are 1,300 feet for the lower, 50 feet for the middle, and 1,313 feet for the upper unit. The amount of stratigraphic thickness missing because of faulting is not known. The amount lost between the lower and middle units may be considerable because of the sharp differences in texture and lithology of the two units. The amount missing between the middle and upper units, however, may be small because the lower part of the upper unit consists largely of limestone and clastic beds similar to those in the middle unit. Lithologically similar beds in the vicinity of Teran Wash on the east side of the San Pedro Valley are reported to be in excess of 3,000 feet in thickness (L. A. Heindl, oral communication, 1952). It is therefore suggested that the total thickness of the Mineta Formation is at least in the magnitude of 3,000 feet in this area.

Fragmentary fossil remains have been collected from a fetid limestone bed near the middle of the upper unit of the Mineta Formation by Dr. J. F. Lance of the University of Arizona. The remains, collected from the SE-1/4SW-1/4SW-1/4 sec. 13, T. 13 S., R. 18 E., Pima County, Arizona, consist of a few teeth and part of a jaw or maxillary from a young rhinoceros. The stage of evolution and the size of the animal suggest a probable early Miocene age (J. F. Lance, oral communication, 1952). An unidentifiable gastropod was also found in the same bed. (Ed. note: The rhinoceros has been identified as Diceratherium sp., of probable Miocene age, by Lance *in* Wood, 1959.)

Several inferences are possible concerning the depositional environment of the Mineta Formation. The conglomerate apparently was deposited very rapidly following uplift of a relatively nearby source. The depositing medium appears to have been intermittent streams flowing first over the surface of granite and later over the beds they had deposited. Deposition may have been in the form of an alluvial fan. The poor rounding of large sand grains in the finer grained detrital sediments also suggests that deposition occurred closest to the source areas, composed predominantly of granitic and metamorphic rocks. The decrease in general size of the detrital fragments toward the top of the Mineta Formation indicates a progressive lowering of the source of the sediments during the time of deposition. The gypsum bed near the top of the formation suggests that inflow into the basin exceeded outflow during at least part of the time of deposition, and the tuff bed indicates at least some contemporary local volcanism. The limestones were probably occasionally deposited in lakes which were formed during late phases of deposition. The silty and black, fetid limestones suggest a warm, moderately humid climate.

Andesite Porphyry

Andesite porphyry crops out in the northern portion of the area as steep-sided hills and slopes and prominent cliffy ledges. The rock is generally red brown, although locally it is gray or black. It is distinguished by large, tabular plagioclase phenocrysts which average about half an inch but may be as long as an inch. These constitute about one-third of the rock. The phenocrysts stand out as grayish blotches against the red-brown matrix, or, where weathered out, they give the rock surface a pitted texture.

The andesite porphyry occurs in large masses and as sills and dikes. The sills and dikes, from 2 to 5 feet thick, definitely cut the Mineta Formation, and some of them can be traced into large porphyry masses. Some of the large porphyry masses are considered to be intrusive, but, in the central part of the area, agglomerate and vesicular zones may represent surface flows. The outcrop pattern suggests that the andesite porphyry, where it is considered to be extrusive, probably lies with an angular unconformity on the Mineta Formation. On the east side of the San Pedro Valley, volcanic flows similar in petrology to the andesite porphyry overlie with an angular unconformity continental sediments similar to the Mineta Formation (L. A. Heindl, oral communication, 1952). The upper surface of the larger masses of andesite porphyry is either eroded off or in fault contact with the Mineta Formation or younger rocks.

The rock is remarkably uniform in composition and texture. One characteristic specimen has the following composition microscopically:

Minerals	Percent
Phenocrysts	
Plagioclase (Ab_{50-60}), averaging half an inch	25
Hornblende, averaging a quarter of an inch	10
Groundmass	
Epidote	28
Feldspar, composition indeterminate	19
Magnetite-ilmenite	9
Kaolinite	9
Quartz and chlorite, less than	1

Intrusion of the Mineta Formation by the andesite porphyry shows that the porphyry is definitely younger than the Mineta. Porphyry fragments in the late Cenozoic fill indicate that the porphyry was exposed to erosion by Pliocene or late Pliocene time. The thrusting which involved both the andesite porphyry and the Mineta Formation is assumed to be pre-Pliocene because the late Cenozoic alluvial deposits are not involved. The andesite porphyry is therefore tentatively considered to be middle(?) Tertiary in age.

SUMMARY

1. The Mineta Formation is a sequence of continental conglomerate, sandstone, mudstone, and limestone of middle Tertiary age exposed on the east side of the Rincon Mountains, Pima County, Arizona. It is composed of three units, separated by faulting, but is considered to be part of a single formation because of compositional and textural similarities.

2. The Mineta Formation is tentatively believed to have been deposited by streams and in playas or shallow lakes in a basin whose local source areas were composed largely of rocks similar to those presently exposed in the Rincon Mountains. The moderate size of the larger fragments and the poor rounding combine to suggest that the source area was nearby and probably not excessively high. The source area probably receded progressively as it was being lowered, and there is no evidence of successive uplifts. As the thickness of deposits built up, shallow lakes developed, some of which had no outlet. One period of volcanism is recorded and the climate is believed to have been warm and humid.

3. The middle Tertiary age, Oligocene(?) and Miocene, for the Mineta Formation is based on fragmentary remains of a rhinoceros of probable early Miocene age located in the middle of the upper unit.

4. Andesite porphyry intrudes and possibly forms flows over the Mineta Formation; andesite porphyry fragments occur in deformed portions of

the late Cenozoic alluvial fill of probable Pliocene-Pleistocene age. The andesite porphyry is tentatively considered to be middle(?) Tertiary because it and the Mineta Formation are equally affected by thrusting that does not affect the late Cenozoic deposits.

5. The age of the thrusting is not definitely known, but it is assumed to be pre-Pliocene or pre-late Pliocene because the late Cenozoic alluvial fill does not appear to be involved.