TERTIARY AND QUATERNARY
GEOLOGY OF THE TUSAS-TRES
PIEDRAS AREA, NEW MEXICO
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OF THE TUSAS-TRES PIEDRAS AREA, NEW MEXICO

by

Arthur P. Butler, Jr.

ABSTRACT

The Tusas-Tres Piedras area, in north-central New Mexico, is 40 miles long and has an area of 500 square miles. It includes a part of the southeastern extension of the San Juan Mountains of the Southern Rocky Mountain physiographic province and a part of the Rio Grande depression, a northward extension of the Basin and Range province.

The main problems of the Tertiary geology are: (1) the age and relations of the formations that are continuous with and peripheral to the compound volcanic dome of the San Juan Mountains and their relations to the deposits, Santa Fe and Abiquiu formations, of the alluvial basins of the Rio Grande depression; and (2) the position of the San Juan peneplain with respect to this sequence.

The rocks of the area were mostly derived from local volcanic centers. They consist largely of stream-laid deposits, detrital aprons, accumulated on the borders of areas built up by contemporaneous volcanism. In addition, they also include minor amounts of tuff, coarse pyroclastic rocks, and lava. The volcanic rocks are quartz latites, rhyolites, and basalts.
Juan region extend southward without lithologic change into the San Juan dome and end in this area.

The Los Pinos formation, here redefined and subdivided, is separated from Treasure Mountain by a considerable time interval but rests upon it with apparent conformity. The Los Pinos is separated from the overlying Hinsdale basalts by an unconformity, here recognized for the first time. In part of the area it is divisible into members: the Biscara (new name) characterized by dark-colored quartz latite; the Esquibel (new name) characterized by fragments of coarsely porphyritic quartz latite, the Jarita (new name), basalt flows; and the Cordito (new name) characterized principally by light-colored porphyritic rhyolite. These individual and distinguishable parts, the pyroclastic and effusive rocks in the formation, and the lithologic similarity of coarse detrital beds to the volcanic rocks indicate that the formation originated as coalesced aprons of detritus about centers of contemporary eruption rather than as the product of renewed erosion on the uplifted San Juan dome as heretofore thought.

The Santa Fe formation of the extreme southern part of the area consists of sandstone and arkose derived from the erosion of granitic and metamorphic rocks. It is continuous with and similar to the formation in its type locality. The divisibility of the Los Pinos formation makes it possible to show that the Santa Fe is in part equivalent to and in part younger than the topmost member of the Los Pinos. As the Santa Fe ranges in age from upper Miocene to lower Pliocene, the Los Pinos is probably of Miocene rather than Pliocene age. Most of the Los Pinos is equivalent to much or all of the Abiquiu tuff of Smith.

The Hinsdale volcanic series consists of: (1) Cisneros (new name) basalt; (2) Dorado (new name) basalt; (3) separated volcanic
piles here referred to as the San Antonio andesite; and (4) the Servillieta formation (new name). The two older basalts, Cisneros and Dorado, are somewhat discontinuous. They rest unconformably on both the Santa Fe and Los Pinos formations. The Servillieta formation, previously referred to as the New Mexico type Hinsdale, consists of basalt and interbedded gravel. It rests unconformably on the older basalts of the Hinsdale volcanic series as well as on the pre-Hinsdale rocks. The formation is partly an alluvial deposit filling a basin that was induced by post-Santa Fe, probably mid-Pliocene, deformation.

The Tertiary rocks are deformed by gentle eastward tilting and displaced on a group of related normal faults. The tilting reflects uplift of the San Juan Mountains on the northwest and relative depression of a basin block on the east. The eastern side of the basin block is probably strongly downfaulted against the Sangre de Cristo range twenty miles to the east. Most of the faults of the area are of relatively small displacement and fall into two zones, the Tusas and Vallecitos. The Tusas fault zone trends north-northwesterly for the length of the area. The main faults that trend with the zone have a maximum displacement of 1,200 feet. Cross faults that offset the main faults have a lesser displacement. Movement on the main fault of the Tusas fault zone occurred twice. Movement was initiated after the close of Santa Fe deposition. Erosion then destroyed most of the resulting relief, and formed a relatively smooth surface on which the Dorado basalt of Hinsdale age was erupted. This basalt was displaced by renewed movement on the fault.

The same evidence proves the existence of a considerable erosion interval between the close of Santa Fe time and the eruption of the Hinsdale basalts. This pre-Hinsdale erosion surface is cut across broken blocks and is not in the stratigraphic position of the
Jarita basalt in the drainage basins of the Los Pinos River and the Rio San Antonio. Subdued summit topography in other parts of the area and benching of the pre-Cambrian rocks at positions that are stratigraphically high in the Los Pinos are probably also evidence of this erosion interval. It seems probable that the San Juan peneplain should be correlated with the post-Los Pinos and post-Santa Fe surface on which the Hinsdale basalts were erupted.

Three and possibly four additional sub-cycles of erosion are represented by accordant ridge spurs in the Tusas Valley. As this valley drains through the Chama to the Rio Grande, these valley stages are imperfectly developed, and the same sequence probably cannot be established, because this stream reaches the Rio Grande across the top of the resistant Hinsdale basalts of the plateau.
Summary of Results

The principal results of the investigation of the Tertiary geology in the
Tucson-Tree Piédras area are to show: (1) that the Los Pinos formation, as
here redefined, is largely equivalent to the Abiquiu tuff of Smith; (2) that
a little of the upper part of the formation is equivalent to part, probably the
lower part, of the Santa Fe formation; (3) that some of the basalt previously
included in the "Hindsdale formation" is, instead, a member of the Los Pinos;
(4) that the Los Pinos formation as well as the Santa
Fe formation is separated from the Hindsdale volcanic series by an unconformity
which may correspond with the San Juan peneplain, and (5) that the
principal formation of the Hindsdale volcanic series, the Sirvilleta, fills
a basin that was induced by post-Santa Fe, probably mid-Pliocene,
deformation. Other subsidiary results also accrued from the investigation.
Locally, the Los Pinos formation can be subdivided into members, and the
Hindsdale volcanic series can be divided into formations. Information
obtained on the nature and age of deformation indicates that there were
two periods of faulting. Structure largely determined the larger
geomorphic features and has affected the physiographic development,
especially of the mountains. Several stages of this development are apparent,
but the data obtained are not sufficient for a comprehensive interpretation of
the local geomorphology.
D I S C U S S I O N  O N T H E  L A T I T U D E  O F  B Y P A S S  C A N Y O N

Dark-colored quartz latite breccia characteristic unit. Also includes unbrecciated lava flows, tuff-breccia, agglomerate, and some fluvialite beds, which range from tuffaceous graywackes to poorly sorted conglomerates. Breccia and flows are generally more abundant in the upper part of the formation, clastic rocks, other than breccia, in the lower part.

Dark-colored quartz latite, near andesite in composition, is the chief rock of the breccias, agglomerates, and flows, tuff-dioritic latite and basalt also occur. Tuffs tend to be pelitic, and the conglomerates are formed of pebbles and boulders of mixed types, in which dark-colored clastic rocks predominate.

Quartz and pyroxene breccia tend to be more pelitic, and the rocks are cherty, with pyroxene and olivine occurring in small amounts. Biotite and hornblende are common phyllosilicates. Biotite is the dominant mineral elsewhere.

Tuffs well-indurated, mineral grains and pebbles in fine-grained matrix grade laterally to tuff-breccia or agglomerate, the matrix of which resembles the tuff, angular, fragip and mold by wet and dry, 4 to 8 stems. No sorting, no bedding, develop spires and pinnacles.

Thickness: has not exposed at thickest point in 52 miles. West of LA 100', else where 1100'. Elsewhere will bridge out completely against pebbles.

Origin - clastic assemblage of clastic & effusive rocks. Nannophylos, distinct lithologic, poor sorting of materials, and angularity indicate that most of the clastic rocks moved short distance in large part by agencies other than running water. The intimate association of clastic rocks with effusive rocks, and the gradation of breccia to tuff-breccia on agglomerate suggest that the various types of rock were deposited nearly contemporaneously, either as the direct result of volcanic eruption or the immediate result of loose material.

Ordinary flow breccia, tuffs, which fragments are set in a tuff-like matrix of different lithology.
some pyroclastics channelled by streams & backfilled by alluvial deposits

Presumed Conejo under Treasure Mountain fm. in Tusca Valley correlated:
1. volcanic activity suggested by water-laid tuff
2. resemblance between basaltic anker & matrix of Conejo cory in this Sanburr Valley
3. stratigraphic position
4. presence of considerable non-volcanic material in Conejo in vicinity of Conejo Canyon
5. similarity of between these & beds under vole pt. & fm. in Summit lab quad., etc.

Treasure Mountain formation - instead of t.m. quary beds & lean & lave,

Distribution and relation to older rocks.

described in Conejo will extend E side of small valley N of Pt. Pico R in
Sec. 33, T 32 N, R 7 E, relief in top Conejo & 320';
1 mi S of San Miguel, top bed of t.m. abuts against edge of Conejo.
Canyon topography found in Colorado but there fen generally lacking,
many places T. M. overlies Conejo & ends on p6.

lithology - rhino & g/t/b beds lava, welded tuff & tuff breccia, t intergrades,
tuff, graywacke, and eq

az. 2.49.3 - upper E flow, horse half tuff
n. side rd San Antonio - upper strata mostly flow.
15 mi S E - tuff more abun.

flow or flow-like nd confined to base of fm. because of topography,
distinctive bed "welded tuff" marker at top.

flow-like nd at base may be welded tuff - all go t like microl.
greyly p t b, certain by flows of similar compro, dull brown & red or n
more abun porphy the ill. nd t g/bf. pheno-plag & bds.

flow-flow more persistent than ill. flow-like nd

25' thick

Applying welded rhynolite - basaltic tuff, weather into charae slabby frag
11 to top of bed - common - thousands at many places quakes from go at top,
though porphy, towel at f. clear in tuff. wht, porph

tab p/q, f. kerman p/mm porph

underground igneous rocks can pop through these little holes, shouldn't
33. Welded agp. 2078 ft. in point of Sarciun, 7 1/2 mi. from

34. Below welded tuff, bed 2 section is tuff & tuff breccia, tuff andes, 55 sq. mi.

35. Intergrade, mid p.t. tuff & flows interbedded in Beam Creek. A decipitating constituent, prints tuff, 14 mi. land from R. A.

36. Origin — accret. unnamed andesite tuff, welded tuff, possibility flows, and water andesite. Breccia, tuff & agp., looks steep initial dips & abrupt changes in

37. welded tuff are lithoidal, mostly massive & unaltered except for locally

38. New Zealand

39. Long comparison with tuff strata in.

40. T.M. well with "water" 60 ft. above tuff, never crossed high hills long.
Los Pinos formation

stratigraphic - quartz-feldspar sandstone & siltstone with some siltstone & sandstone beds, dominant in region of the Río Grande. The formation is characterized by its distinctive color, ranging from white to gray, and its fossil content, which includes dinosaurs and other prehistoric life forms. The Los Pinos formation is often overlain by the Rincon formation, which marks a significant stratigraphic boundary.

Distribution - the Los Pinos formation is widespread throughout the region, with outcrops located in the mountains and valleys. It is particularly prominent in the Río Grande Valley, where it forms a significant part of the landscape. The formation is known for its distinctive layers, which are often visible in the landscape, providing a glimpse into the geological history of the region.

Subdivisions - the Los Pinos formation can be divided into several distinct layers or beds, each with its own unique characteristics. These layers are often distinguished by their color, texture, and fossil content, providing valuable insights into the geological history of the region. The formation is divided into several distinct members, each with its own unique characteristics.

In the vicinity of the Río Grande, the Los Pinos formation is overlain by the Rincon formation, which marks a significant stratigraphic boundary. The Rincon formation is characterized by its distinctive color, ranging from red to brown, and its fossil content, which includes dinosaurs and other prehistoric life forms. The formation is often overlain by the Walnut Park formation, which marks a significant stratigraphic boundary.

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Undivided gravel member - sheet 47 section 4 of Las Cruceses (p.449).

- Lithology: Predominantly graywacke, tuffaceous graywacke, fine-grained gray

- Mere sept. vert. distrib., more tuff near bottom. relat, present.

- Cg 3m at 100' below top.

Generalized strat. section in NC T30N R7E n.1 Pic San Antonio =

Santa Fealt member

Undivided Los Pinos

- Not exposed, probably fine-grained fluvo-tidal beds

- Greenish brown, indurated sandy graywacke

- Cg cemented by chalcedony, cliff forming

Conglomerate and interbedded graywacke or
tuffaceous s."; tuff; boulder tillered slopes

Tuffaceous siltstone, fine-grained tuffaceous
graywacke; may include some tuff

Conglomerate, angular; dark-colored,
andesite-like fragments in a matrix of
tuffaceous graywacke

Total undivided Los Pinos

Treasure Mountain fm. - not measured

Tuff one fb. 1' in min. grain in frag matrix partly chertified, gray,
small 1" peb. uniformly distributed, thin some beds.

Color commonly light gray, but ranges from light buff to cream white.

- Partly parted 15 grey晱e uniform distrib. thin entire fm. grade to 55 tuff silt

- 2 gaze = cg 15 qa, same or buff, lt. brown. beds 1'/-4' feud

- X. bedding common. 1' qa peb. qa 15, the main consist of 55 greydeaux.

- Some pebb, boulders, gray qa present. - chert zone qa w/ good cl. suggest

- Short transport - few 10's miles

- Cg, little surface residual nodule. Cg beds 1' less, max 10'

- Lenses & pockets common. sorting good. good.

- Thicker beds peb-crb 4'-6' in diam.

- Larger beds 4'-4' equidimensional. beds 15 largest pheno.

- In gen. small pebbles well rounded, thicker.

- Along outer edge of outcrop 15 cm to 3m rounded.
p. 52 - phenoclast mostly vol. no. mainly firmament, pelites

Many de-cal and-like pel remainr with of F. underlying carbon &
Finrava mem. Partic. amy. in lower pt. present thin all.

flax & CB gyx maroon ore phyl fel 15cm phono. fel. are common.
their pel. in channel fillings. unlike any other at in area a large quad.

53 - NO peb. of Tres. Mt. XJ found in Los Pinos fan, even close to contact.

Biscara mem. - type Kanada Biscara 137 E.

character by abim. & phenoclast. F. gray de-colored qt. late. breccia & cg.
potentially correlative w/ ph. of Smith's Abiquiu tuff.

55 - can be subdivided into 3 pts. distinguished by abim. &

56 de-cal qt. lat. clays. pc. wet. in coarser beds.
abim. tuff. same color. some peb. in mid pt.

57 - can be divided into 3 pts. distinguished by abim. &

58 - de-cal latite - let gy-ge, & marn.-gy & f.f.

59 pel. phyl. finely X-line & q. ph.

60 - char. by the abundance of peb. & ph. late. 

61 Cupeb. mem. - characterized by the abundance of peb., & ph. late. 

62 similar in lith. & under. Biscara N. of Break Off Mt.

63 - gy. q. py-pch q. late. & pho. pho. & pho. & pho. 

64 transitional to underlying breccia.
- Enchanted View area, upper main hill of pt of
  believed to be core of largest of individual bowl of 10 ft. flare.

Jantar basalt member -

- some of basalt interbedded w/ tuff in Abiquiu quad part. correlator

1. northern type a. - fine, slightly paph, void vein, rusty interdug,
   chal amyg. - more common in bottom of both present
   b. - fine, more porphyry, no intra pore space,
       rusty vein CaCO3, CaCO3 amyg., pheno pyr

2. southern type - basalt, small veing pydo. or yel.veg spots
   super. all 1 plac. gain mostly short
   sparse pheno of pyro. into pore space
   dense type w/ rusty interdug, plag.
   all qm pyr. than il incorporate.

3. central type - fine and porph, abran. veig. vesicle
   tad plac. 2-5 mm. rusty interdug
   some flow w/ sparse qz & dol qm pyr.

thickness to 100!

 Cordite member

- predom rhigo, largely flow tels, fine, grad. modst. to ceq
  all minor bit veig. tuff & ils

- ceq frags = 1. rhynolite rx - sparse & grad. porph. rh, qz, qz, 
   9.5, saus. 

  2. porph rx - medium foliation, 0.5-1.0 cm. & 2.0 cm.
   rhynl & qz, br, qz, 
   some bioc, br, 9.8. qz, apl matrix

- Animal interval preceding the Cordite member is apparently of only
  local significance

- few small dikes & plgs of pm-pink qtz of this age

No Aurora Mountain rhynolite - eroded ensnared of why not of the site.

NW Tularosa 454.6 cm., S 128N 87.90, 1700
1. Origin - their design do not fit concept of Atwood & Reimer's work.  
   2. Alluvial fans from rendered uplift of San Juan R. 
   3. Visible evidence that alluvial fans are results of older volcanic eruptions. 

Chaparral pertinent to origin: 1. loose flows, breccias & tuff until w/ alluvial step 
2. many large tuffs in gravel, similar to indicated eruptions 
3. kind of deposits change systematically from west to east. 
4. Many of these fans in Cycl differ from pre-obs Pino outcrops & San Juan R. 
   that may not lie within a distance from which such large fans could have been transported. 
5. Changes in lith of fan were marked from N & S than W & E 

182. indicate much material from active volc centers 

83. change in eruptive character: 1. & 2. a change in lava flow.
   3. undivided flows from multiple sources. 
4. Some buried by Tucos Mt. at least 20 mi. to N.W. 
   5. Old lava beds from other sources, 
   6. biggest builders in Río San Antonio near Los Pinos R. 5.9 'dream. 

84. 5. undifferentiated sources different from those dep. Río E. Q. Coe's change in lith. must be result of streams traveling transverse to long axis of this area. 

85. Smith's idea that the source of the Abiquiu Tuff was in the central part 
   of the Tucos quadrangle is obviously invalid. However, his basic inference 
   that the source was north of the area mapped by him is correct. 

86. Indirect evidence of E or N-E source of Los Pinos = 
   1. all data points to east source for Santa Fe 
   2. Santa Fe outcrops of vents in E. Pt.  
   3. Surface slopes W or SW. 
   4. all known vents of younger basalt, etc. in Baja Cyma are on E. Pt. 
   5. Tucos plateau has been an area of eruption during a long period. 

87. Lava flow & pumice. 1. large 6 steps indicate local origin. 
   2. many places note against possibility interfering debris. 
   3. fresh cracks & absence of evidence cutting into bed from p.c. suggests 
   4. relatively dry climate.
Section 1. Cenozoic formation on north side of the Rio Piers Ria in NW 40231, T32N R2E

**Cenozoic formation**

- Quality: Latite breccia, gray-green, possibly near nephrite in composition
- Qtz lat: massive & tuff flows, pum-puk, pink to pur-gy, phenocrystal glass, matrix, 30% phenocrystals in aph granodiorite, phenocrystal matrix closely similar
- Qtz lat, qz-gy & gy, in andesite in camp, interbedded as gl and bid
- Qtz lat, m. and in camp, in ph. clinrite latite, dark green, gy graphite, some play & matrix indigo after this, interbedded as gl and bid
- Qtz latite, mostly qz & gy, gray & gray-green, interbedded with tuff flows & breccia 95%. This lat, locally the breccia altered to
  - Local unconformity —
  - Qtz lat, qz-gy, 90% qz & gy, pink near-matrix in breccia
  - Phenocryst-rich breccia, phenocrystals like plagioclase in phenocrystal
  - Breccia of light colored fragments in tuff matrix, qz-tuff & gray qz

Tuffaceous 55 or graywacke, gray
Not exposed to level of Rio Piers Ria

Total thickness measured

Vertical range of exposure 765', tuff and andesite in direction
and amount
Treasure Mountain Formation, top
Welded tuff of quartz latite, gray to pink, massive
Tuff, pink, friable - general resemblance to underlying welded tuff
Slatey schist, gray or bluish gray, interbedded with tuff, 8 feet thick
Tuff, buff, fine-grained, gyrolite tuff
Sastagrande, buff, fine-grained, tuffaceous
Cobble scree, well-cemented scree, sandy scree
Tuff & tuff breccia, fine-grained, interbedded with scree
Poorly exposed, mostly tuff & tuff-breccia, some interbed water-laid
Hydroclastic tuff or tuff-breccia, massive, cemented but not in this section closely associated with tuff or red-brown flows

Conglomerate
Olivine latite, gray, grayish, massive, somewhat papyraceous, plane of cleavage, plagioclase feldspar, olivine, and magnetite

Total Treasure Mountain
275
Tuff, tuff, pt, fabric, carries chroxy frag, fumic & bio flake
SS, eff, alca, & 55% of frag & pt
Tuff, fragmental, ind, cr ls, chroxy frag of fumic, grains of ft, & bio
Rhydetite flow, stit lsition, slightly ppol, phenu fl, & bio in qth ground
No exposure, prob cr & frag & pt

Total measured thickness 20
Creeks surface
Sanita basalt member, 3 flows or flow units
Undivided gravel member
Sedimentary beds, not exposed
SS & cg, interbed, well-ind, cm by chal. 5:6, some SS-agglomerate at bot 10
Gyrite, tuffa, lt-hum-avg, well-bld, partly ind; tuffa SS, gray-tuff 110
Cg & SS-cg, of mixed frags, dark-colored gray lat & small parch gray lat frag 40
Tuff, smt.-bld, mmtr to thin bld, inter-bld thin lenses tuffa cg-gyrite 65
Cg, tuffa, small-pel, & tuffa gyrite
Tuff, pel, mmtr, porous bld, bols qft lat cg blcks to 2' diam 65
Cg, large bld, mostly dl sort qft lat, partly sorted pel cg & tuffa gyrite & wngn pt
Cg, sm. pel, L dt-cl. qft lat, grades up to tuffa gyrite, scattered blds, pel, blcks, some thin blds cg, L small pel
Tuff, some lenses of cg & conspic. pprcl. frags qft lat
Tuff, tuffa, well-bld, & pgrnd tuffa gyrite
Chips of tuff, scree, pprcl. frags of pumice
Tuff & tuffa gyrite, well-bld, qft, some thin blds w/pumice frag

Total thickness measured
Credito member

Gravel slope, top not exposed
Sandstone, friable, partly tuffaceous, buff, poorly exposed
SS, well ind, muddy, lt brown, w/ local lenses of Cg in
upper 1/2, mostly frag ryho, some qtz, basalt & basalt
Poorly exposed, pub. friable, lt brown SS w/ local lenses of Cg
Cg lenses, subCa frag ryho in matrix of muddy sand,
local beds of muddy SS
Cg, tuff; gy & Qt peb of ryho & some scoria less
Not exposed
Tuff, rather white, pel, & brown, grading to underlying beds, poorly exp
SS, aleuroid, creamy gy, tuff at top w/ white frag decomposed glass
Cg, in upper pt, aleuroid w/ angular flakes of more
Slightly Cg in lower pt, poorly exp toward top & base
Total Credito member measured 193

Sanita basalt member

Fri - 2 basaltic flows, some Cg

Biscara member

Cg of frag pc w/ pub. top Exposed mem but mapped as Biscara
Local unconformity
Cg, tuffa, frag of Qt & Cg, lat, same frag caly, graphite, ptz, poorly exp
Tuff & peb tuff, prismatic; Cg, ryho, mixed w/ gravelly Qtz
Lat tuff & tuff bre; dips steep & irregular
Base not exposed

Total Biscara & Sanita members 158

Total thickness measured 357
Table 3—Tremolite clinopyroxene from NW corner unnamed T. 130N., R. 6E., 1.5 mi. S. of highest on Rio San Antonio, 17 miles west of San Antonio ranger station. Analysis by J. G. Falekild

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(from Falekild, unpublished manuscript)
STRUCTURE

General Statement

area in transition zone, N & NW domes arch, and up & dissected - Santa Fe
E & S depression of structural trough w/ post-Pliocene:
relief in low plateaus & valleys of Los Angeles Depression

In this area, W is also deformed & main geologic feature is expression
of larger structural elements somewhat modified by erosion.

PT structure not studied. However, structure of Tumaca represents
lesser features superimposed on a larger block that is composed of pre-Tumaca,
chiefly PT, W, & Tumaca lines marks line of culmination
of major uplift which structure has not been completely worked out.

This tilted block ends along W of Sangre de Cristo where pre-Palos
are abruptly uplifted, prob. by normal faulting.

W in Tumaca-Tres Piedras area the dip of Tumaca consists of general
eastward tilting & nodal displacement as a group of related normal faults.

Structure of the area proper

Tilting = Dip 4-6° west, locally near faults to 25-30°

reversals w. dips usually WSW in direction of downthrow.

Cerro has local dips < 6°, initial dips of escarpment was:
basins younger than 4000 yrs rarely < 30

Tres Piedras with acute strike N15-35°W

Life more northly

Original dip of last Pino from NW to SE - Today's trend direction

Faults = partial en echelon arrangement into 2 fault zones - Tumaca & Vallecito fault zone.

2 sets but part of 1 system.

"main faults" - larger, trend W/E general strike of the fault zone;

"cross faults" - short, transfer displacement from one main fault to another, they are an integral part of system.

Criteria of faulting - newly exposed, abrupt repetition of strata, 1 st displacement of distinctive beds, bedding kinks. Older fault scarp

Silicification in Santa Fe Valley & NW.

Linearity only planned, not worked. Older main faults involves
dip 70-80° NW.
Tusco fault zone - 44 mi in max 51.5 mi in.
Significant fault or 2-3 small faults.
Max. width zone 3 mi.

Potasa Range N - 12.5-30W trend to zone
1 mi S, Serrillos Plaza 67°W dip.

1 mi mid 84, T32N R28E, 77°W NW dip on small fault.
Almost no exception the west side of main fault is downthrown.
Small graben 1.25 mi N of Serrillos Plaza.
Main faults not persistent along strike - die out or abruptly offset by X-fault.
Potasa Range - 10 mi long.

Some branch into 2 faults that continue for miles.

Thus branch & die out.

Block diag fig. 27 shows in each w/ X-faults.

Figure 27 shows 2 faults.

Strike faults.

Displacements noted marked on fig. 27.

X-fault zone. N40-65°E
2 types X-faults: a) those that offset a trench, displacement on main faults from 1/4 to 1/2
b) those which do not appear to affect the position of the main fault, only a few of these have been mapped.

2, 3, 4 in fig. 27 important X-faults. Cause drainage change.
N side down.

5, 6 - type 2 X-faults, either side down.

Type 1 do not cross main faults.
Lackening rather than breaking of strata.

Vallecitos fault zone = only partially mapped
at least 2 main faults & related X-faults. N40W trend in map.
EGN in adjacent quadrants.

Incompleteness data, combined displacement 1,600' max, 1,200' min.

Other faults = 8, 9, 10, 11 lie outside Tusco fault zone & independent.

7 branches NW from Tusco fault zone 1 mi W Bear's Off. Hill.

No. 10 present in San Ildefonso mine line at S. end.

Show well in contactite at inclined mine level. Pid Sam Antonio &

No. 10. Strike N20-45W, faults both trends of displacement here 1,000'.
Two periods of movement on faults: All known faults are younger than Los Prios fault. Post-younger than Santa Fe & pre-Dorado fault.

2nd movement after Dorado & partly after Servilleta faulted also.
Post-Servilleta faulting is inferred by first stage EXP. of one place east of Camanche Canyon in T 26 N. R 10 E. isn't general evidence of def. of faults.

2nd movement not present in Santa Fe fault.

Petaca Mesa shows 2 deforms well.

fault 2 - 2 dip = 90° pre-Carmen 20' post

renewal of faulting general rather than local cause.

pre-Servilleta faulting cannot trace & contrast with Servilleta to be distinctly different from those that prevailed during the deposition of the Los Prios beds.

Age of deformation =

pre & post los Prios only deformations with visible record in this area


early fault: renewed fault: movements = basin for trench dips.

Blanco Basin on tilted fault.

pre-Bajada Valles faults: N & S fault in N E R 15 Grande Dep (upper)

El Rito from Eure (?)

probably uplift & erosion to PS in this area

no evidence of def. between Postos & los Prios as inferred by Atwood & Waley.

San Juan PLanform post: post: los Prios.

accum of basin deposit (Santa Fe, los Prios) implies some deformation

1st episode Post-def. recorded post: Santa Fe & late Pliocene.

interval of erosion, extension of Carmanile & Dorado between.

2nd episode post these: exact age not known.

suff. time to reduce 500' relief caused by 1st def.

probably def. is pre-Servilleta.

Further east tilting during 2nd post-Servilleta.

erosion, faulting along Sangre de Cristo - pre-cutting of los Grande Canyon.
Regional relation of the structure

Faults & dip result of movements forming Red Hills depression

Units are more or less symmetric & asymmetric blocks.

Espanola basin is greater-like near symmetric.

Tuolumne basin is unequal - asymmetric.

Skipton basin - asymmetric.

is lower pt. of block depressed along its eastern margin into Alamosa basin if San Luis Valley.

faults in detail subsumed on large tilted blocks.

may be injunction of tensions resulting from domal uplift on NW & Sinkings of area of E & SE.

2 periods of movement on some faults suggest reg. movement spasmodic rather than continuous.

Geomorphic aspect of structure

Depression is major geomorphic feature because depressed while adjacent areas, equipants, remain, have been uplifted.

In NW pt. of depression uplift on east side affected by normal faulting.

On W side, Tuolumne Mtn & S pt. San Juan Mtn are uplifted & portion of a large tilted block.

Dep. driven Red Hills depression & bordering areas into series of sub-11 steps or blocks that trend N. Sep structural blocks the details of which subsequent physiography develop W in the blocks has differed.

Structure is chief factor which controls physiography modified by stream action.

Rio Vallecito & Tuolumne Creek located on lower sides of tilted block, their separate posterior potholes consequent on faulting & def. of block, but the valleys are largely eroded as they lie in beds of softer beds or subgray.

Tuolumne Mtn, rising, from Ten Plateau, largely because of differ. of structure that is expressed by greater relative uplift of the mtn & greater deformation of W soil, which inclines then.
Fault, showing downthrown side

Inferred fault

Rectangle shows position of block diagram
Summary of the Geomorphology

Introduction

Paramount post is SE extension of San Juan peneplain.
post. post-Las Tunas rather than pre- as defined by Atwood & Mathen.

Uplift development post-Dorado complicated by:
1. sea level for stream draining N pt area diff. from streams draining S pt. of Dorado Mts.
2. faulting w/in area has caused degree of erosion to be different on the E & W sides of the tilted block.
3. Tectonic plateaux undulated by 200 yr. than nature of history not seen.

Position of the San Juan peneplain

name for extensive, extant, sub-summit surface developed during long erosion

173: internal post-Fisher's latite-andesite. bed lying deep in this surface following
uplift of central San Juan; peneplain completed in late Pleistocene according to Mathen
with cord beds into W Fisher's latite-andesite
i. N/Mex. has been rest or 1 bed of Cretaceous for 120 my. mi.

174: suggest absence of vigorous & widespread erosion

must evidence of long post-Las Tunas erosion prior to Shubel Vac.

Summit surface: 600-800', 200-250' prior R m N

5. ridge of San Agustín in 30N R 7.8E now was stabilized ~3001

175: after present-day

in SW pt. area remain eliminated 400-500' relief caused by
post-Santa to faulting & produced low relief surface on which Dorado uplifted

176: pt. at Tachichios is bench at level where Las Tunas could be surface cut
& on which Scalinata basalt now exposed.

Mata de la Santa upland is post-Las Tunas - does not coincide w/to Geography

Much intensive work needed on geomorph.
<table>
<thead>
<tr>
<th>Event</th>
<th>Upper Tuaco Valley</th>
<th>Lower Tuaco Valley</th>
<th>Rio San Antonio</th>
<th>Los Pinos River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Santa Fe pre-pluvial erosion, San Josean plain (?)</td>
<td>Divide east of valley</td>
<td>Surface under pluvial base east of valley</td>
<td>Accretion ridges north and south of stream about 200 feet above present grade</td>
<td>Upland of the drainage divide north of stream; 600 to 800 feet above grade</td>
</tr>
<tr>
<td>Stabilization 300' above present grade in upper Tuaco Valley</td>
<td>Ridge spur 330 to 400' above present grade</td>
<td>Not represented (?)</td>
<td>Accretion ridges about 300' above present grade (?)</td>
<td>RIDGE SPUR 500' above present grade?</td>
</tr>
<tr>
<td>Early Tuaco Valley and surface cut terrace</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>250-350' Terrace</td>
<td>Possibly same as preceding intervals, possibly unrepresented</td>
<td>Broad valley spur represented by spur 200-300' above stream</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>150-250' Terrace</td>
<td>Does not extend above</td>
<td>Ridge spur 100-150' above stream</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
Cross, Whitman, Howe, Eames, and Ramus, E.L. (1925) Silverton Fold, Colorado, U.S.
, and Lane, E.S. (1925) A bibliography of the geology of the San Juan region of Southwestern Colorado, U.S. Geol. Survey, Bull. 543.
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29 July 1960

Dr. Richard H. Jahns
Division of Geological Sciences
California Institute of Technology
Pasadena 4, California

Dear Dick:

(Sec. Note: the tape was not clear at this point, hence the first couple of lines are missing here.)
because I am leaving in the morning for Iceland and I suspect unexpurgated version of some of my ideas concerning the Ojo Caliente quadrangle. In the first place, the geologic map has been completed. I suspect that it is time now for someone to go into the quadrangle and do the geology of the area. I had to rush in places in mapping the surrounding areas at the rate of 2 to 6 square miles per day. In some places a little more detailed work might show up further features. However, I am certain that the main picture is correct and that there are sufficient details for the scale of our map. I did not get a chance to make a geologic map of that one mine that you wanted done, Dick, up north of Cerro Colorado. I suggest the possibility of further work in the area would be very useful in the southern part of the area, a detailed study of the Abiquiu stratigraphy, south of Arroyo El Rito. There are several unconformities and different lithic rock types to map, cross beds studies, etc., to give the history of the Abiquiu deposition here. Thirdly, I had no opportunity to go back and try to zone the metamorphic rocks. You will find on the geologic map numbers which are note numbers concerning rock samples I collected, most of them oriented for potential petrofabric studies that maybe some eager type around here would want to do under Ingerson's or Clabaugh's eagle eyes. I'll try to discuss the quadrangle by regions and, therefore, I hope I can record here all of the ideas before they fade away on me. My copy of my map has yet to arrive from Socorro, so I am doing this with a blank topographic quadrangle in front of me, a vivid imagination and a series of notes I had written while living in Ojo Caliente expecting to have to do this dictating now.
Central Transfer Area. - The central Precambrian area was mapped by walking the metarhyolite and amphibolite beds. These marker beds plus crossing some of the other units at occasional places gave me enough control to drag through the contacts through the entire area. You will notice that I abbreviated the symbol system on the Hopewell series rocks by leaving off the "PC" designation. There is so doggoned much data that is going to go into that little area that I suspect that we will have to use simplified notations for the Precambrian rocks. Secondly, I did not bother to transfer any of the dip and strike data or other structural data that was on the original field sheet by Jahns. I suspect that after the contacts are on and the draftsman picks out some representative dips and strikes the map is going to be so confounded cluttered already that it might be best either to refer the reader to the "on file" copy or possibly even have that few square miles around Cerro Colorado enlarged and published in an enlarged scale as a separate inset map. The only real thing I noticed in the Precambrian area was in your note number 6 where there was a considerable amount of cordierite and, I would guess, kyanite in the metasedimentary rocks there. Otherwise I think the grade of metamorphism is constant along strike. This may be a local high or low or something and it is within the unit labeled "OPX". The Ortega quartzite seems to be uniformly within the sillimanite grade as you suggested, including the little inclusion on Cerro Colorado, in spite of what is shown on Corey's manuscript where he describes the La Madera Mountains' material as kyanite. The little red lines in the Precambrian area are pegmatites; the blue ones, quartz dikes. Some of these are ones that I added, others were just simply copies of the ones that were on the original field map. In the northern part on Owl Cliff's Tufa are three notes labeled "DFH", for D. Foster Hewett, which represents samples of the travertine that I collected for him. Those can obviously be ignored and deleted. The few places in the La Madera Mountains I could by using the cross-beds make absolutely certain that the dip and strike that I recorded on the map was right side up or, conversely, upside down. In those places I have marked little arrow with a "Y" at the end of it pointing in the direction of younging of the beds. I started a crude attempt there, in other words, to unravel the folding in the quartzite. I didn't have time to do a decent job and probably there are many more folds than are shown. I also get the impression from the appearance of the porphyrytic phase of the metarhyolite that occupies the core of Cerro Colorado that it is identical to the coarse porphyritic granites that I have in my Brazos Peak (?) quadrangle and it is equivalent I believe to the porphyritic phase of Barker's tusas granite. If this is true, then our
metarhyolites are post the orogeny rather than pre the orogeny as Barker has inferred, or possibly the porphyritic phase is simply not metarhyolite at all, but represents the tusas granite that has come in as sills and bodies into the same general area that the earlier metarhyolites had also intruded. I am just wondering, in other words, about our intrusive history here which might be the final answer. I thought of this too late in the game and never had a chance to go back and to field check any spots that might be critical to unravelling the history. We probably ought to discuss this with Barker, too, but I have gotten a very strong impression that the porphyritic phase at least is equivalent to Barker's tusas granite and my rocks to the north which are nearly circular in map plan, plutons that are obviously cross-cutting the earlier metasedimentary materials.

Northeast Corner. - A tremendous maze of faults can be seen in this part where it is well exposed and they probably continue farther northeast except that in the upper Cañon Seco there are very poor exposures and not much opportunity to delineate at all well. The sedimentary structures and cross-beds are well exposed in the badlands in the south half of Sections 5 and 6. The Caliente conglomerate of this region is kind of a hybrid that is all composed of quartzite debris, derived from the La Madera Mountains and therefore it is of many ages, much of it older, some of it probably even younger than the surrounding Santa Fe formation. In places you will notice on the map that I have marked the indication of the mudflow terrace deposits sitting on the old high level terraces that are between 60-68 feet in elevation.

East Side. - Santa Fe in this region is generally two segments. The lower portion is fluvial and the upper is practically all sand dune deposits and the cross-beds of the sand dunes almost invariably dip in a nearly easterly direction indicating the winds then were practically constantly westerlies during the time of formation of these dunes. One of the problems along the flanks of the high mesa there is when are you looking at dunes of Santa Fe age and when are you looking at recent cover of dunes that are apparently forming today. There is a tremendous smear of that type of thing in that area. You will notice also a very short line indicating the approximate boundary between the lower and the upper subdivisions of the Santa Fe. I made no attempt to try to map it everywhere, but you
will notice in places the Santa Fe symbol having a "D" at the end of it indicating that it was dune material. You will notice also a new symbol all over the map, a little arrow and some suffixed letters associated with it; these arrows are all cross-beds, the "X" indicates cross-bed, the "A" in Abiquiu lithology, the "D" indicating dune lithology and I think that is all, at least all that I can think of right now. It has a zone of cemented beds that may actually be a stratigraphic zone that outcrops in a pretty linear pattern, but anyway there is a suggestion by the cementation in this particular area of a fault, as shown by the dotted line and the question-marked word "fault" written along it. It may be better to leave it out completely.

The terrace cap of the mesa has pumice and tuffaceous sands in the lower 1/3 of it in the southwestern part, mostly in the northeastern quarter of Section 19. The notes on the gross stratigraphy of the terrace cap in that area is shown on the map. This pumice material has left a (Secretary's note: the tape was not clear at this point and I believe there is a phrase left out) bag from both of the two outcrop areas sampled, only the sample 16 has good pumice fragments. I wonder if they are from the great Jemez caldera. (Sec. Note: a phrase is missing here).... also have come from No Agua Mountain which is north of Tres Piedras which is the only other locality that I know of that has pumice and rhyolitic material of that late geologic age. Anyway, it adds a little spot for study, research and correlation and we can have a grand time with it or ignore it.

Southeast Corner. - The southeast corner was quite frustrating because there is a recent dune cover over everything and therefore virtually nothing to see. Arroyo Cavilan has a tremendously soft sand bottom, so I doubt if it would be passable for even a four-wheel drive vehicle. The cross-beds in the Abiquiu formation in the southeast and eastern belt, as you can see, are generally south to southwest. Quite a contrast to the cross-beds over in the western side of the area which generally trend south to southeast. It may be that these represent streams that were coming from the north because the Abiquiu is equivalent to the Cordito member of the Los Pinos formation and that must have been derived from the north, so these streams then were probably filling the fans in around Cerro Colorado accounting for a cross-bed preference slightly toward the center of the map area instead of straight due south. It is possible to drive to the old abandoned windmill shown just south of Arroyo Cavilan over by the east corner of the map. I don't think you could cross the arroyo and drive on northward and get in any closer to the terrace mesa in that portion. You can't get on to the high mesa from
the east side because of a continuous fence. Incidentally, about a half mile east off the sheet is a high flat-top of basalt capped peak that is a very intriguing looking thing. Even though I walked on the east and south flanks where sandstones, tuffaceous sands, and volcanic bearing conglomerates are found in nice bedded layers that are dipping inward under the cap, with the cap itself of a basalt the likes of which I don't recognize because it is not at all like the Hinsdale flows that form the big mesa cap a few miles farther to the north and east. Those flows are quite coarse grained and holocryptalline. The basalt capping the little peak is very fine-grained and dense and an olivine basalt. It may be an event, on the other hand, it may simply be outlying remnants of basalt of unknown, as yet, source area.

**Northwest corner and west side.** - This is one of the most monotonous areas in the entire quadrangle--practically no exposures, most of it appears to be not only of Santa Fe, but of dune type Santa Fe. The upper surfaces of the long ridges are probably graded, but there is no real harmony to them today because of the later erosion. There is a thin gravel veneer on some of it and the gravel itself suggested that it was let down from the original terrace surfaces. The fault north of State 96 is well located in a few places as indicated by virtually a solid line, the rest of it is dashed because of its approximate location. The fault must die out very shortly south of the highway, although the exact spot I don't know. The exposures, again, are kind of poor. Incidentally, about a 100 yards west of the northwest corner, going out that little crummy road that shows up on the map is a tremendous outcrop of Precambrian quartzite, just barely missed the map, fortunately, or we would have had another gloop of color up there.

**Area south of Arroyo El Rito and Cerro Negro.** - This is the most fascinating portion of the post Precambrian outcrop areas. Unfortunately I was a little pressed for time and spent only three days field work in the whole area. It deserves more time to do the details of the Abiquiu stratigraphy and to study the sedimentary and volcanic history that is so well exposed in it. The area that you have on the map marked as "giant scour and fill structures" is actually a little outlying remnant of a spectacular unconformity within the Abiquiu formation. The best exposures of the unconformity are along that cliff face and surrounding the area labeled "Tba". That area includes the flows and flow remnants, volcanic
breccias, agglomerates, and assorted volcanic junk that represents to me a moving, flowing mass of volcanic material filling a giant channel. That material, as you can see from the dip and strike data, is strikingly unconformable on the older Abiquiu that has been folded and then maybe possibly even faulted in a few places. It has been doubled in this big channel area. It was then filled with the volcanic material, probably in part from Cerro Negro, but also from the dikes that are seen cropping out in this region. So the stratigraphy appears to be this within the Abiquiu sequence here: a lower, purplish sand and silt (this is best seen in the northeast quarter of Section 28); these are overlain by a green and brown sandstone; then, there was an interval of folding and erosion; then this volcanic activity; and, then, unconformably across those, the unit marked "Post-Tba". Now, this "Post-Tba" starts with brown sands and silts that are really just a thin lower unit and they are immediately overlain again by purplish colored conglomerates composed of volcanic material that is typical of the Abiquiu of this area. East of the north-trending fault and east of the outcropped area of "Tba", the stratigraphic column is a little bit different wherein it has a brown sandstone that is between purplish colored silts, sands, and conglomerates. This brown sand unit thins eastward very rapidly. The suggestion I make at the moment is that the unconformity on top of the brown unit is probably the same unconformity as the one on top of the "Tba". Some of this area I was mapping during a blinding rain with the result that all of the major features are right, but that somebody probably ought to check the strike directions of some of the dip and strike data along say the middle of Section 35 and 34 in that region south of Arroyo El Rito. A lot of those dips and strikes were eyeballed in from a distance that gets the dip, amount, and approximate direction and put down the approximate strike just by eye onto the map. The two major fault zones that you can see here, the one that would then pass west of Cerro Negro and up around Cerro Colorado and the one then passes into the Ojo Caliente valley apparently trend on to the southwest into the Medanales quadrangle where they seem to be the equivalents of the big cemented walls of fault material that are down there in the southern part of that quadrangle.

General comments on Abiquiu, Santa Fe stratigraphy. - The contact between the Santa Fe and Abiquiu is a little problem in places because of the inter-bedding of the two types of lithology. In particular, northeast of Ojo Caliente where I first started, you will find a unit marked "TAS" Abiquiu-Santa Fe inter-bedded which I started to map and then decided that this was ridiculous, I will pick the contact where Santa Fe lithology above it is virtually 100% of
the section. There may be in places one or two thin beds, each a few feet thick above that contact line. Below it, I have left all of the inter-beded material in as just part of the transition zone, then, between the Abiquiu and the Santa Fe. In other places, there is a very sharp, clearcut break between Abiquiu lithology and Santa Fe lithology. In particular the area west of the northern part of Arroyo El Rito which is well shown there were I have the contact drawn. I have a good picture, incidentally, of that area in the northwest quarter of Section 8, Township 24 N, Range 8 East, that probably would be easily converted to black and white and be an illustration in the report.

Faults. - Faults are of at least two ages within this area. The faults that break the Precambrian, many of them are also pre-Caliente conglomerates. The best exposure of that is in the new roadcuts south of the bridge in Section 1, north of Ojo Caliente, where metarhyolite is faulted against the quartz micabiotite schists and the fault itself in both of these units is buried by a thin veneer there of Caliente conglomerates. The other systems of faults are obviously post-Santa Fe and pre the high terraces that are at least 400 feet above the present stream level. Those terraces are not faulted as shown in several places, the best one being up northeast of Ojo Caliente in Sections 5 and 6.

Miscellaneous Items. - How about the possibility that the oldest high terraces are equivalent of the Ancha formation of Baldwin?

You asked me to see what I could do with that long ridge north of Cerro Colorado and whether I could pull through some of the Precambrian units there. I am convinced that the ridge itself is composed of residual detritus that may, in part, have been Caliente conglomerates, but, anyway, it certainly has a mappable cap of unconsolidated materials today. By fighting along that steep back slope along the fault zone, I found contacts of some of the Precambrian units there that crudely coincide with the ones that we can trace so well to the east. So, it is, at least in part now, broken down and subdivided.

I gave the cross sections a brief looking over and as far as I can see they are all drawn correctly. I suspect that they will have to be redrafted again to fit the new scale; maybe not redrafted, but at least they could probably photographically reduce them to the new scale and then have the topography corrected slightly and I suspect that they are all ready to go.
PLEASE NOTE THAT ARCHIVAL NONACID PAPER HAS BEEN PUT BETWEEN SOME OF THE PAGES OF THIS REPORT. DO NOT REMOVE! IT IS TO HELP PRESERVE THE LIFE OF THIS REPORT.
TERTIARY AND QUATERNARY GEOL OGY
OF THE TUSAS-TRES PIEDRAS AREA, NEW MEXICO

by

Arthur P. Butler, Jr.

- - - - - - -

ABSTRACT

The Tusas-Tres Piedras area, in north-central New Mexico, is 40 miles long and has an area of 500 square miles. It includes a part of the southeastern extension of the San Juan Mountains of the Southern Rocky Mountain physiographic province and a part of the Rio Grande depression, a northward extension of the Basin and Range province.

The main problems of the Tertiary geology are: (1) the age and relations of the formations that are continuous with and peripheral to the compound volcanic dome of the San Juan Mountains and their relations to the deposits, Santa Fe and Abiquiu formations, of the alluvial basins of the Rio Grande depression; and (2) the position of the San Juan peneplain with respect to this sequence.

The rocks of the area were mostly derived from local volcanic centers. They consist largely of stream-laid deposits, detrital aprons, accumulated on the borders of areas built up by contemporaneous volcanism. In addition, they also include minor amounts of tuff, coarse pyroclastic rocks and lava. The volcanic rocks are quartz latites, rhyolites and basalts.

The Conejos formation (quartz latite) and the Treasure Mountain formation (rhyolite and quartz latite) of the Potosi series of the San
Juan region extend southward without lithologic change into the San Juan dome and end in this area.

The Los Pinos formation, here redefined and subdivided, is separated from Treasure Mountain by a considerable time interval but rests upon it with apparent conformity. The Los Pinos is separated from the overlying Hinsdale basalts by an unconformity, here recognized for the first time. In part of the area it is divisible into members: the Biscara (new name) characterized by dark-colored quartz latite; the Esquibel (new name) characterized by fragments of coarsely porphyritic quartz latite, the Jarita (new name), basalt flows; and the Cordito (new name) characterized principally by light-colored porphyritic rhyolite. These individual and distinguishable parts, the pyroclastic and effusive rocks in the formation, and the lithologic similarity of coarse detrital beds to the volcanic rocks indicate that the formation originated as coalesced aprons of detritus about centers of contemporary eruption rather than as the product of renewed erosion on the uplifted San Juan dome as heretofore thought.

The Santa Fe formation of the extreme southern part of the area consists of sandstone and arkose derived from the erosion of granitic and metamorphic rocks. It is continuous with and similar to the formation in its type locality. The divisibility of the Los Pinos formation makes it possible to show that the Santa Fe is in part equivalent to and in part younger than the topmost member of the Los Pinos. As the Santa Fe ranges in age from upper Miocene to lower Pliocene, the Los Pinos is probably of Miocene rather than Pliocene age. Most of the Los Pinos is equivalent to much or all of the Abiquiu-tuff of Smith.

The Hinsdale volcanic series consists of: (1) Cisneros (new name) basalt; (2) Dorado (new name) basalt; (3) separated volcanic
piles here referred to as the San Antonio andesite; and (4) the Servillleta formation (new name). The two older basalts, Cisneros and Dorado, are somewhat discontinuous. They rest unconformably on both the Santa Fe and Los Pinos formations. The Servillleta formation, previously referred to as the New Mexico type Hinsdale, consists of basalt and interbedded gravel. It rests unconformably on the older basalts of the Hinsdale volcanic series as well as on the pre-Hinsdale rocks. The formation is partly an alluvial deposit filling a basin that was induced by post-Santa Fe, probably mid-Pliocene, deformation.

The Tertiary rocks are deformed by gentle eastward tilting and displaced on a group of related normal faults. The tilting reflects uplift of the San Juan Mountains on the northwest and relative depression of a basin block on the east. The eastern side of the basin block is probably strongly downfaulted against the Sangre de Cristo range twenty miles to the east. Most of the faults of the area are of relatively small displacement and fall into two zones, the Tusas and Vallecitos. The Tusas fault zone trends north-northwesterly for the length of the area. The main faults that trend with the zone have a maximum displacement of 1,200 feet. Cross faults that offset the main faults have a lesser displacement. Movement on the main fault of the Tusas fault zone occurred twice. Movement was initiated after the close of Santa Fe deposition. Erosion then destroyed most of the resulting relief, and formed a relatively smooth surface on which the Dorado basalt of Hinsdale age was erupted. This basalt was displaced by renewed movement on the fault.

The same evidence proves the existence of a considerable erosion interval between the close of Santa Fe time and the eruption of the Hinsdale basalts. This pre-Hinsdale erosion surface is cut across deformed Los Pinos beds, in part below the stratigraphic position of the
Jarita basalt in the drainage basins of the Los Pinos River and the Rio San Antonio. Subdued summit topography in other parts of the area and benching of the pre-Cambrian rocks at positions that are stratigraphically high in the Los Pinos are probably also evidence of this erosion interval. It seems probable that the San Juan peneplain should be correlated with the post-Los Pinos and post-Santa Fe surface on which the Hinsdale basalts were erupted.

Three and possibly four additional sub-cycles of erosion are represented by accordant ridge spurs in the Tusas Valley. As this valley drains through the Chama to the Rio Grande, these valley stages are imperfectly developed, and the same sequence probably cannot be established, because this stream reaches the Rio Grande across the top of the resistant Hinsdale basalts of the plateau.
Summary of Results

The principal results of the investigation of the Tertiary geology in the Tecos-Tres Piedras area are to show: (1) that the Los Pinos formation, as here redefined, is largely equivalent to the Abiquiu tuff of Smith; (2) that a little of the upper part of the formation is equivalent to part, probably the lower part, of the Santa Fe formation; (3) that some of the basalt previously included in the "Hinsdale formation" is, instead, a member of the Los Pinos; (4) that the Los Pinos formation as well as the Santa Fe formation is separated from the Hinsdale volcanic series by an unconformity which may correspond with the San Juan peneplain; and (5) that the principal formation of the Hinsdale volcanic series, the Sevilleta, fills a basin that was induced by post-Santa Fe, probably Pliocene, deformation. Other subsidiary results also accrued from the investigation. Locally, the Los Pinos formation can be subdivided into members; and the Hinsdale volcanic series can be divided into formations. Information obtained on the nature and age of deformation indicates that there were two periods of faulting. Structure largely determined the larger geomorphic features and has affected the physiographic development, especially of the mountains. Several stages of this development are apparent, but the data obtained are not sufficient for a comprehensive interpretation of the local geomorphology.
Laguna formation - was instead of L. andesite.

23. Dedicated lithology - dark-colored quartz latite breccia characteristic unit. Also includes unbrecciated lava flows, tuff-brecia, agglomerates, and some fluvialite beds, which range from tuffaceous graywackes to poorly sorted conglomerates. Breccia and flows are generally more abundant in the upper part of the formation, elastic rocks, other than breccia, in the lower part.

Dark-colored quartz latite, near andesite in composition, is the chief rock of the breccias, agglomerates and flows, tuffite latite and breccia also occur. Tuffs tend to be tuffite, and the conglomerates are formed of pebbles and boulders of mixed types, in which dark-colored lavas predominate.

24. Mixed breccia. Tends to break around the fragments, but the more jelly, purg-ry to red por fhe, break across frage.

In composition, the flows rocks range from basalt to andesite latite, quartz latite, and the breccias from divine latite to quartz latite.

25. Lighter - plag, dol, py, iddingsite after divine are common phases. Bis, rare.

26. Tuffs well-indurated, mineral grains & ang pth in fine-grained matrix grade laterally to tuff breccia or agglomerate, matrix of which resembles the tuff encouraging frag ang & mud nnd b p at 4' diam.

No sorting, no bedding, develop spires & pinnacles.

Thickness - does not exceed at thickest point in La Piu Canyon 2 mi. W of 10th R. 6 to 1000', elsewhere will wedge out completely against pth.

Origin - elastic assemblage of elastic & effusive rocks.

27. Angularity indicates that most of the elastic rocks moved short distance in large part by agencies other than running water. The intimate association of elastic rocks with effusive rocks, and the gradation of breccia to tuff breccia or agglomerate suggest that the various types of rock were deposited nearly contemporaneously, either as the direct result of volcanic eruption or the immediate reworking of loose material.

Ordinary flow breccias & breccias in which fragments are set in a tuff-like matrix of different lithology, were violent mechanism.
Some probably mudflows
Some pyroclastics channelled by streams & backfilled by alluvial deposits

29. - Presumed Conglomerate, Treasure Mountain fm in Tucumcari Valley concluded
1. volcanic activity suggested by water-laid tuff
2. resemblance between lentonicite andesite & matrix of Conejo cgy in the San Juan Valley
3. stratigraphic position
4. presence of considerable non-volcanic material in Conejo in vicinity of Conejo Canyon
5. similarity of between these rx & beds under the Pt. of fm in Summerville, 
quadrant, etc.

30. Treasure Mountain formation - instead of T.M. quartz breccia & andesite layers
Distributed and relation to other rocks.
disconformable & well exposed at side of small valley NW of Pt. of fm in Sec. 33, T 32 N, R 27 E, vicinity of top Conejo & 300
1 mi S of San Miguel, big bed of T.M. about against slope of Conejo.
canyon bypass found in Colorado's but there few generally lacking,
many places T.M. overlap Conejo & rocks of pt.
lithology - rhyo & qtz breccia, welded tuff & tuff breccia, & intergrade
Q. 2, P. 93 - upper 1 flow, lower half tuff
R. side RD San Antonio - upper strata mostly flow.
15 mi S - tuff more abundant.
flow is flow-like rx confined to base of fm, because of tuff sometimes
distinctive bed "welded tuff" marker at top.
flow-like rx at base may be welded tuff - dol e.g. & till mix,
graphite & tuff, overlain by flows of similar comp.
more common than all rx & aphan. pheno - plagi & feld,
tuff flows more persistent than tuff flow like rx.

32. - Tuff welded phylolite - latitite tuff, weather into chara, slaty, pheno
11 to top of bed, commonly ph-e.g., at many places grades from e.g. at top
through ph-e.g. & red at bot. ph-e.g., firo e.g. & aphan., pheno
plagi, feld, more primary gey pgy - pheno
under ph-e.g. - groundmor - more a less well preserved tuffite, tuffite free, chalk chara.
Welded tuff not 100' thick in extreme SE corner of 20 N 14 E.

This W & S so that along highland W of Beaver Creek it W 15' thick. Pinches out N & S limit 43'.

Covered 160 sq. mi. in N. Mex. + large area in Colorado.

Many places reaches 10' pinch to tuff, massive but friable, pelitic tuff.

Good cap 12 mi. S E in Little & Coe near on D A R E.

Contact undulatory W inoculation of underlying beds into the welded tuff.

34. Below welded tuff, bulk of section is tuff, tuff breccia, tuff breccia, silt, silt intergrades, mud pt, tuff & flows interbedded.

in Beaver Creek a decapitating buttunite, pinch tuff, - W. bank.

Canada Creek has bed stilted, highly similar altered.

Fine-grained clastic < 50%, 15% felds, Suba - well rounded & well-worn.

Cg bed 1-15' trans. & sand feldite or and feldsem. avg. 0.5-1.0 the n. & e.

Welded-tuff at top only way to distinguish from underlying to Pinatubo.

in S. Low, unweathered T1N R6E SSW along E side Pecos Valley a conoid. pphn. phts. pht 6' some beds nearly all derived from pt. n. of river, soil.

Some beds in E of 161.0, breccia of hillside rubble.

Thickness - 320' on N. side has knis 60' M. S. limit of stop.

35. Origin - accum. named airborne tuff, welded tuff, possible flows, and water-laid. Top tuff & e. Ledge steep initial dips & abrupt changes in lith. If Coine E. gen. aren bedded so that individual bed can be traced.

center a centermost occ. act. features from N. Mex. than pt. Coine.

Arenaceous cg in beds fine grained suggest parental streams that were graded rather than coarse & delta. Scoured & filled their channels.

Welded tuff is lithoid, mostly massive & unlimbed except for locally

virious base, rather uniform fine-grained

in compact aspect similar to welded tuff in Okla., Bishop, Calf., "equifine"

Of 3. New Zealand

in comp., text., size similar un-welded tuff. O. Valley 10,000 sq. mi. Calf., Utah.

37. A 0 - long comparison w/ Tuff's east origin.

T.H. - well sorted, uniform fine gr. pht. Never airborne, never covered high, till foreign rock present only locally. Some amount f upper tuff on love.

avg. thickness 25' - 1 cu. mi. per in N. Mex. may be distinct like genuine

flows of Magana.
Los Pinos formation

Atwood & Walker - gravel and outwash plain deposits of underlying Hudspeth sandstones. Type locality in vicinity of San Miguel - 600'.

Scattered deposits mainly 55' and 70', and tuff and tuffite.

Carr & Lassen well drilled in Hudspeth.

Butler retains main line to west as junction. Sep. by uncanny from Hudspeth.

Distribution - most widely distributed unit in map area.

Atwood & Walker present in vicinity of Briones Canyon.

Some for E of El Pinto Creek mapped as Abiquiu by Smith, while Los Pinos ph. if not all of Abiquiu is equi. & ph. of Los Pinos ph.

Subdivisions - not uniform laterally or vertically.

S. of Bestac Off Bluffs - from into 4 mem. - (1) 3 mem. disting of each other by color. Kind of the flag consists largely of water-laid gravels, cm., breccia w/mineral cemts of tuff & volc. breccia; (2) mem. basaltic lava.

N. of Bestac Off gneiss not worked - undivided gravel = "Los Pinos gravel."

Atwood & Walker = lower mem. of Los Pinos.

W. of Tiras Creek is shown as undivided - 2 clastic members are present; not enough time to map.

"In the vicinity of the Pelican Mesa the top member of the formation grades laterally from water-laid volcanic gravel and pyroclastic rocks to arenites, sandstones, and sandstone that are continuous with the Santa Fe formation of the Abiquiu quadrangle."

Flag of changes in strat. from E to W across Tiras Mitre appears to be less than the changes from N to S.
p.48 - Undivided gravel member - strat. section 4 of Rio San Antonio (p.95)
49. lithology - prd. graywacke, tuffaceous graywacke, fine-grained eq.
more spct. vert. distrib., more tuff near bottom - relit. persist.
Cq zone r~100' below 60'.
Generalized strat. section in NC TSO N R7E n. 8 of Rio San Antonio.
Santur Baselit Member ------------------------------------------ 50'
Undivided los Pinos
Not exposed, probably fine-grained fluvioth. beds 50'.
Greenish brown, indurated sandl. graywacke
d eq. cemented by chaledony, cliff
tuning 50'.
Conglomerate and interbedded graywacke or
tuffaceous ss'; topp. boulder cliffed slopes
Tauffaceous siltstone, fine-grained & tuffaceous
graywacke, may include some tuff 150'.
Conglomerate, angular, dark-colored
sandstone - like fragments in a matrix of
tuffaceous graywacke 100'.
Total undivided los Pinos 600'.
Treasure Mountain fm. - not measured

Tuff are felic., 2' win gains in frag. matrix partly densified glass,
small ss. peb. uniformly dist. thru some beds.
Col. commonly light gray, but ranges from light buff to cream white
poled out ss. graywacke uniform dist. thru entire fm. grade to stiff silt
or graywacke -eq. lt eq., same lt buff, lt. brown, beds 1'-6' thick 1'.

51. X. bedding common. 2' gains fl. gfs, the main consist. of ss-graywacke
Some peb. ss. mag. gfs. present, because gfs w/good cl. suggest
short transport - few 10's miles
Cq. little surface - residual rubble. Cq beds 1'-less, max 30'
Lenses & pockets common. Sorting rel. good.
Thicker beds peb-coh 4' in diam.
Larger flakes 4' generally in beds to 2x largest phenoclasts.
in gen., smaller frag. subjung, less well rnd than larger.
along Rio San Antonio, lower cq <1', then 200' above bore more end.
p.52 - phenocasts mostly volc. in. mainly fumitens- plagioclase.
Many de-coal end-like pelb resemble 6lth in. of underlying longco &
of Búcaro mem. Pumice, abun. in lower pt. present than all,
felds & clb gq. maroon. Cov pebb. fel 1.5cm. phen. fel are common,
their pelb in channel fillings - unlike any other at. in ama a longco grad.

53 - No pelb of Texas Mtn. at. found in Los Pinos fin. even close to contact!
Búcaro mem. - type Kanada Búcaro T22N R8E
character at abun. of phenocasts if gq. de-coal gq. latte. busca. 4 ecg.
pbably correlatives w. pt. 6 Smith's Abiquiu tuff.

55 - can be subdivided into 3 pts. distinguished by rel. abun. of
56 - de-coal gq. lat. phyr. pt. w. in common beds.
| | gq. latte. ism. in lower pt. |
| | all plagioclase & small phen. pelb. |
| | abun., phen. in upper pt. rel. to bed. at ecg. |
| | close to pt. hills. has. members are unmelted pebbles of gq. &

57 - some abun. beds
similar to lower Abiquiu tuff

58 - all ch latte. - at gq. gq. is man. gq. & fel.
all phen., finely x-line & q.g. & bl
poy. slow small pelb common phen.
adding to gq. after Abiquiu gives mast-spotting

59 - pale gq. spots comma - prob. altered gq.
both present in same
pettiot, f. these are strat. abou Búcaro.
phen. busca. 70' in SE Búcaro Canyon. All-gq. gq. & fel
also small ch f. & phen. in this memera

61 - Esquerbel mem. - characterized by the abundance of pelb, cts, plb.
| | of composites. pelb gq. latte.
| | recog. into weat. pt. R7E.

| | gq. a pum. pink gq. latte. w. composite. fel phen. 5 & 8 mm.
| | fol. pelb. also pres.
| | transitional into underlying Esquerbel memera.
65. - Equidistant view, eucalyptus field hills, 9 pt. Skt., believed to be corner of largest part of uninfused line of 11 pt. fence.

Santeri basal member.

66. - Some of basalt interbedded w/tuff in Abiquiu quad. pub. correlative.

67. 1. northern type a. - fine, slightly pearly, woolly, nicely interbedded.
   chalcopyrite - more common in bottom of both present.
   b. - fine, more porphyritic, less inter por sp.
   some thin CaCO3, CaCO3 amygd, plagiogr.

68. 2. southern type - basalt, small inclusions, qtz, qtz, qtz sp.
   sugar, alkali plagioclase, gives rusty color.
   some plagioclase, thin inter por sp.
   dense type w/nasty interbedding, plagi.
   some qtz, qtz, thin aq, inc.

69. 3. central type - fine grd, porphyritic, alumina, vesicles.
   thin plagioclase, 2.5 mm, nasty interbedding.
   some plagioclase w/sparse qtz & dol qtz pyro.

70. - Cordito member.

71. - Predominantly large, large, flow beds, fine-grained andesite & coar qtz.
   w/mineral inclusions: tuff & lava.

72. a. qtz plag = 1. rhodolite, no. - sparse to porphyritic.
   8 mm, red, pm, 9.8 gr.
   2. porphyritic, coarse kind.
   0.5 to 10 mm, to 2 cm
   Some biotite, qtz, qtz, qtz.
   qtz matrix.

73. - A small interval preceding the Cordito member is apparently of only minor local significance.

74. - Few small dikes & plugs of purplish clay of this age.


76. - Cordito 250, 650, 650. - Mead & Boulton 1700; 600-700, 600, 700; 650-700, 650, 700, 800, 800.
There is no tangible evidence that alluvial fans are result of older volcanoes.

1. Flows, debris & tuff into alluvial dep.
2. Many new flows in gravel petrology similar to interbedded eruptions.
3. Kind of tuff on sections systematically from one center to another.
4. Many of the larger fans in are different from pre-160 Pino vents of San Juan Mts. That carry out wide in a direction from which such large fans could be transported.
5. Changes in litho-facies were marked from N to S than W to E.

53. Indicates much of material from active site centers.

3. Change in eruptive character, new or change in loco-geometry, undivided pts. from multiple sources.
4. Cañon buried by Tucos Mts. for at least 20 mi to NNW. . . . old-colon.

5. There are different sources different from those dep. Bio., Eq. Ged's change in litho-facies must be result streams travelling transverse to long axis of this area.

55. Smith's idea that the source of the Abiquiu tuff was in the central part of the Tucos quad is obviously invalid. However, his basic inference that the source was north of the area mapped by him is correct.

56. Indirect evidence of NW or NE source of Los Pinos:
1. All data point to east source for Santa Fe.
2. Santa Fe basin from vents in E pt. of E of mapped area.
   a. Surface slopes W or SW.
      all known vents of younger basalts, etc., in Braga range, are on E of Tucos.
      Tucos plateau has obviously been an area of eruption during a long period.

57. Many places volc. NE against WE, W/O intervening debris.
   Fresh utters + absence colored clayey matrix in bed from WE suggests relatively dry climate.
Section 1, Congo formation on north side of the Los Pinos River in NW 1/4 Sec. 1, T32N R7E

Congo formation

Quartz latite breccia, gray-green, probably near ignimbite in composition
Qz lat. mamies & brecc. flows, p.p. pink to purplish, phenocrysts & plagioclase, 5 cm cubes. Chonsgn, in aphy grout matrix, frag & matrix nearly similar.

Qz lat. gy-gn & gy, in breccia in camp, interbedded aggl & brecc. lq lat. in camp, in p.p. olivine latite, dk greenish, gy phenocrysts, some plagioclase, weakly indurated after this, interbedded aggl & brecc. 40

Qz lat. breccia, mostly gy & gy-gn, are alternating & interbedded with striped flow & breccia, pref. oliv. lat., locally nk bleached white by alteration, which includes silicification.

Agglomerate w/ lge rounded frags in tuff matrix, interbedded with tuff & breccia, mostly gy & gy-gn, fills channel in underlying local unconformity.

Qz lat. gy-gn breccia, pasted gy-gn to pub mamies frags in matrix, gy matrix, phenocrysts & plagioclase, 5 cm cubes. interbedded breccia & aggr. of lge random frags in tuff matrix, gy breccia & gy tuff & gy breccia, gray

Tuffaceous 55 or graywacke, gray

Not exposed to level of Los Pinos River

Total thickness measured

Vertical range 10-65, dips vary in direction

675 ft
Section 2. Treasure Mountain formation on north side of Washo River, sec. 33, T. 32 N., R. 7 E.

Treasure Mountain formation, top

1. Welded tuff of gray to white, gray to pink, massive

2. Tuff, pink, friable — general resemblance to overlying welded tuff

3. Graywacke, large clasts, white, light gray, and gray, interbedded with large clasts and thin layers

4. Tuff, buff, fabric overlies fine-grained, white tuff

5. Sandstone, buff, fine-grained, buff-colored

6. Cobble clasts, well-cemented overlies gray sandy clast

7. Tuff & tuff breccia, fabric, gray to white, interbedded, carries 5% red clay in medium to poorly exposed areas. Mostly gray tuff & tuff-breccia, some interbedded sandstone.

8. Rhythmites tuff & tuff-breccia, massive, elsewhere but not in this section closely associated with tuff, tuff-breccia, and interbedded sandstone.

9. Total Treasure Mountain

15 feet

Conglomerate

10. Gravels, light to medium, gray, gray, feldspar, massive, somewhat pebbly, pebbles & cobbles, light gray, flag, silty & intercalated with thin lenses of ash.
p.47 - section 3, Treasure Mountain formation near southern limit of exposures

15°, 7.28 N., R. 8 E.

Top not exposed, indefinite, probably consist of cg & f sub frag. 10Pc
Tuff, felic, pl, fusible, carried chalky frag. & pumice & bio flakes
So., rhyolite, & 55 cg. of frag. & pc. 10Pc
Tuff, fragmented, ind., qy-hum, chalky frag. of pumice, grains of f. & bio.
Rhyolite flow, stnt bump, slightly porph., pheno f. & bio in apl. gndr. 20
No exposure, prod.cg. & frag. & 10Pc

Total measured thickness 20
Section 4. Undivided horizon extending on the east side of the Koeckstein, Sec. 5, T.30 N., R.7 E.

Erosion surface

Sedimentary beds, not exposed

Tuff, black, well-beded, cm. by chalcedony, some ss. amygdales at bot.

Ca = ss-cg, mostly cgd, qgt at bot, partly ss, grade up to tuff qg. 15

Cg, ss-cg, mixed fragments ale. chalcedony qgt at bot. 10

Cg, tuff, well-beded, partly ss, grade up to tuff qg. 6

Cg, tuff, small pebbles, qg, tuff qg. 3

Cg, tuff, well-beded, grade up to tuff qg. 6

Cg, ss-cg, mixed fragments ale. chalcedony qgt at bot. 10

Cg, tuff, well-beded, grade up to tuff qg. 6

Tuff, some lenses of cgd, qgt, grade up to tuff qg. 3

Silt, tuff, well-beded, grade up to tuff qg. 3

Rhyolite tuff - breccia, qg, grade up to tuff qg. 3

Tuff, qg, tuff qg, well-beded, qg, grade up to tuff qg. 3

Total thickness measured

5.97
Section 5: Composite section of the lower part of the Concord member, the Santa Ana member, and part of the Biscara member of the San Gorgonio formation on the east side of Tucson Creek, Dec. 19, 29, T.27N., R.9E.

**Concord member**

- Ground slope, top not exposed
- Sandstone, friable, partly tuffaceous, buff, poorly exposed
- SS, well-ind., muddy, lt brown, w/l/ local lenses of cg. in upper 1/3, mostly flaky chloro, some gt, lat & basalt
- Poorly exposed, ptb. friable, lt brown SS w/local lenses of CG
- CG lenses, sub 40% flaky chloro in matrix & mudysand, local beds of muddy SS
- CG, tuffa, grey <10% pely & chloro some serio b想念
- Not exposed
- Tuff, marlled white, fl., & brown, grading to underlying beds, poorly exposed
- Ss, calcare, cream, grey, tuffa at top w/white flaky decomp glass, slightly cg. in lower pt., poorly exposed toward top & bot.

**Santa Ana basalt member**

- 24-2 basaltic flows, some cg

**Biscara member**

- CG, flaky, pt w/pel top Esquimel mem. but mapped as Biscara
- Local unconformity
- CG, tuffa, flaky, lt red, gt lat., some frag caly, graph. cl., poorly exposed
- Tuff & pel tuff, pinkish-red, abys., mixed w/gl. gravelly, pt
- Lat. tuff, tuff li, dike split & irregular, base not exposed

Total Biscara & Santa Ana members

Total thickness measured
Table 3—Tresumac Mountain welded tuff from NE corner unwarped Ti:SOE, R. C.E., 1 mi. S.E. of highway at Red San Antonio, 7 miles west of San Antonio ranger station; analyses by J. G. Fenchel.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Norm</th>
<th>Model</th>
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<tr>
<td>SiO₂</td>
<td>75.79</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>11.63</td>
<td></td>
</tr>
<tr>
<td>Fe₂O₃</td>
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<td></td>
</tr>
<tr>
<td>FeO</td>
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<tr>
<td>MgO</td>
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<td></td>
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<tr>
<td>CaO</td>
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<tr>
<td>Na₂O</td>
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</tr>
<tr>
<td>K₂O</td>
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<tr>
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<tr>
<td>MnO</td>
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<tr>
<td></td>
<td>Sum</td>
<td>99.66</td>
</tr>
</tbody>
</table>

(florum, 437, 9.35, 61.88)

(from E. Deisen, unpub manuscript)
STRUCTURE

General Statement

Area in transition zone. N & NW dome arched up & dissected = Sutuar Mtns.
E & S depression & structural trough W. Ext. Pleist. erosion =
relit. low plains & valleys of Ohio Grande Depression
In this area, Nx also deformed & main geomorphic feature are expression
of larger structural elements somewhat modified by erosion
Pt. structure not studied. However, structure of Tce. nx represents
less deformed area large block that is composed of pre-Tce.
Chiefly pt. nx. W. pt. of Tce. Mtns. marks line of culmination
Of major uplift & which structure has not been completely worked out:
This tilted block ends along W. pt. Sangres de Cristo where pre-Tce
nx abruptly uplifted, prob. by normal faulting,
W. in Tce.-Trespedes area the dt. of Tce. nx consists of general
eastward tilting & mod. displacement of a group of related normal faults

Structure of the area proper

Tilting = Dip 4-6° east, locally var. faults to 25-30°
unusual. dip usually NW in direction & climatcs
Cerro has local dips <6° - initial dips & ease & radius nx
basalts younger than 6oo pt. rarely <30
Trespedes with qoy stikes N15-35\W
South more noticeably

Original dip of 6oo pt. from NW to SE, Today Qtw direction

Faults = partial en echelon arrangement into 2 fault zones. Tce. & Vallesvera
fault zone
2 sets but part of 1 system,
"main faults" longer, trend w/ general strike of the fault zone
"cross faults" shorter, transfer the displacement from one main
fault to another & are an integral part of system

Criteria of faulting - rarely esp. abrupt repetition of strata &
displacement of distinctive beds, Pecos Mesa - eroded fault escarp
intersection in Santa Fe beds - dip 45\W
Elsewhere only planes of minor faults n-1 to main faults measured
dip 70-80° NW or SE.
Tusman fault zone - 44 mi in area & extends S
Single fault or 2-3 sub faults
Max. width zone 3 mi.

Section near N - N25-30W trend of zone
1 mi S. Swinetta Plana 67°W dip
1 mi N. sec 24, T2P N R8E, 77° WNW dip on small fault
Almost w/e except for the west side of main fault is downthrown
Small geyser(s) 1.25 mi N of Swinetta Plana.
Main faults not persistant along strike. Die out or abruptly offset by X-faults

Some branch into 2 faults that continue for miles.
Others branch & die out.

Block fig 27 shows each w/ X-faults
Strike faults

158 Because relat. steep dip, strike faults, start then = dip slip.
Displacements noted marked on fig 27

X-faults gen N 45-65°E
2 types of X-faults nee.: 1) thin that affect a Trumps displacement on main faults from 10 mils
2) thin which do not appear to affect the position of the main faults

2, 3, 4 in fig 27 important X-faults. Cause drainage change.

5, 6 - type 2 X-faults. Either side下车

Type 1 does not cross main faults
Flattening rather than bending of strata

Vallecras fault zone = only partially mapped
At least 2 main faults & related X-faults N40°W trend in map
E & W in alpine quad

161 Incomplete data, combined displacement 1600' max., 1200' min.

Other faults 8, 9, 10, 11 lie outside Tuscan fault zone & independent.
7 branches NW from Tuscan fault zone 1 mi W of Brook Off Mountain.
No. 10 passes into 2 small chenier moraines at S end.

See well in Santa Rosa in inclined pipe beds, Red Sea Antiques &

Stiles N20°SW. Similar to Tuscan fault zone & pipe displacement has 1600'
2.62 - Two periods of movement on faults. All known faults are younger than Los Pinos fault, prob. younger than Santa Fe & pre-Dorado fault.

2nd movement after Dorado & possibly after Serrillota fault also.

Post-Serrillota faulting is inferred only from topo. Exp. at one place east of Ceramache Canyon on T. 12N., R. 10E. in general evidence of def. of fan.

163 - 2nd movement not present on Serrillota fault.
1/2 mi E. D&R G. pumping sta. in Las Pinos R. canyon opposite Santa, Serrillota unit.

164 - Pecos Mesa show 2 def. well.

fault 9 - 2 def. 40' pre-Edwards 20' post

165 - Renewal of faulting general rather than local cause.

pre-Serrillota faulting caused from e. & north. Of Serrillota to be distinctly different from that that prevailed during the deposition of the Los Pinos & others.

Age of deformation =

* post Las Pinos, only deformations w/ visible record in this area.

Deformed crest & w. in Ed., Sange de Cristo = Ceramache?

early Test - renewed Test. Movements = basins for tecton deposits.

Blanco Basin on leveled crest.

pre-ceramache Valles and Ojo in N E of Grande Dep. (upper)

166 - El Rito from E (near?)

higher staff

probably uplift & erosion to PE in this area.

no evidence of def. between Potrero & Las Pinos as inferred by Atwood & Walker.

San Juan peneplain probably post- Las Pinos.

accum. of basin deposits (Santa Fe, Las Pinos) implies some deformation

167 - 1st episode 9th Def. recorded post- Santa Fe or late Pleistocene interval of erosion, extension of Ceramache & Dorado fans.

2nd episode post this, exact age not known.

suff. time to reduce 500' relief caused by post-Def.

probably def. is pre-Serrillota.

148 - Further east tilting during 9th and post-Serrillota.

Sage faulted along base of Sange de Cristo, pre-cutting of Rio Grande Canyon.
Regional relation of the structure

faults & dip result of movement forming Rio Grande depression

Units are more or less symmetrical & asymmetric structures

Épaulement form is greater; like - near symmetrical
Tusse - Tuolumne region - asymmetric

is lower pt. of block depressed along its eastern margin into Alamosa basin & San Luis Valley

faults as detail superimposed on large tilted blocks.

may be expression of tension resulting from normal uplift on NW & sinking of area to E & SE.

2 periods of movement on some faults suggest reg - movement is sporadic.

rather than continuous

Geomorphic aspects of structure

Depression is major geomorph. feature because depressed while adjacent areas, resp. into areas, have been uplifted.

In N pt, depression uplift on east side affected by normal faulting
On W side, Tusse Mtns & Spt San Juan Mtns are uplifted as portion of larger tilted block.

Def. holds here Grande depression & basining areas into series of sub-11 strips & slots that trend NW. Sep. structural blocks the details of subsequent physiography develop within the blocks has differed.

Structure is chief factor which controls physiography, modified by stream action.

Rio Valleé & Tusso Creek located on down sides of tilted blocks.

Their respective portions pos. consequent on faulting & dip of blocks, but the valleys are largely maximal & as they lie in bedding of softer beds are subparallel.

Tusse Mtns disting. from Tuolumne Plateau largely because of shift of structure that is expressed by greater relative uplift of the mtns & greater deformation of NW that underlies them.
Summary of the Geomorphology

Introduction

Paramount pub. is SE extension of San Juan peneplain.

pub. part of line rather than pre- as believed by Alvord & Mathew.

Physo relief Development post-Dorado complicated by

1. Base levels for streams draining W pt area differ from streams draining Cpt & S pt. of Tsus Mtn.

2. Faulting W/in area has caused details of erosion to be different on the East & West sides of the tilted area.

3. Tsus Plateau undulated by 1717 ft more than intro of history not same.

Position of the San Juan peneplain

name for extensive, eroding, sub-summit surface developed during long erosion interval post-Fisher latite-andesite. Basaltic deep on this surface following uplift of Central San Juan, peneplain completed in late Pli - Recent. Alvord & Mathew further corral b(body) & Fisher latite-andesite

in N.Mex. basaltic rests on 1 bed of Tsus Mtn for 120 sq. mi.

suggest absence of major & widespread erosion

mush evidence of long post-basaltic erosion prior to Tertiary time.

Summit surface 600-800' above le Pino R. in N.

540 ft above N.P. San Antonio in T.30N R.7.8E river was stabilized at 1300' above present grade.

in SW part area region eliminated 400-500' relief caused by post-Santa Fe faulting & produced low relief surface on which Dorado extended

176 pE area Tucumcari is bedded at level where le Pino could be surface cut & in which Scrubland basalt was erupted.

 Mesa de la Santa upland in post-le Pino - doesn't coincide with topof.

Much erosion work needed in geomorph.

177 in vicin of le Pino R. remnants of summit surface much too high to correspond W/ broad valley developed in eastern pt. of basin during Florida cycle by erosion of Alvord & Mathew. Only known basin interval in the San Juan Mtn W/ which their development might be approximated correlated is that during which the San Juan peneplain was developed. Seems likely, \& San Juan peneplain, or erosion surface related to it, are post-le Pino rather than pre.
<table>
<thead>
<tr>
<th>Event</th>
<th>Upper Tusco Valley</th>
<th>Lower Tusco Valley</th>
<th>Rio San Antonio</th>
<th>Nco Pimo River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Santa Fe pre-Te fords form San Juan plains (?)</td>
<td>Divide each valley summit west of divide</td>
<td>Surface under hills east of valley's</td>
<td>Accordant ridges north and south of stream</td>
<td>Upland of the drainage divides north of stream; 600 to 800 feet above grade</td>
</tr>
<tr>
<td>Stabilization 300' above present grade in upper Tusco Valley</td>
<td>Ridge spur 300' to 500' above present grade</td>
<td>Not represented (?)</td>
<td>Accordant ridges about 300' above present grade</td>
<td>Ridge spur 500' above present grade (?)</td>
</tr>
<tr>
<td>Fill in Tusco Valley and surface cut through</td>
<td>Erosion terrace or fill at 70-100' above present grade</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>200-300' terrace</td>
<td>Possibly same as preceding intervals, possibly not represented</td>
<td>Broad valley represented by spurs 200-300' above stream</td>
<td>?</td>
<td>Spurs 300' above stream</td>
</tr>
<tr>
<td>100 -150' terrace</td>
<td>Does not extend above</td>
<td>Ridge spur 100-150' above stream</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>


Denny, C. S. (1940a) Tertiary geology of the San Acacía area, New Mexico, Jour. Geol., vol. 48, p. 73-106.


—— (1938) Tertiary geology of the Abiquiu quadrangle, New Mexico, Jour. Geol., vol. 46, p. 933-965.


29 July 1960

Dr. Richard H. Jahns
Division of Geological Sciences
California Institute of Technology
Pasadena 4, California

Dear Dick:

(Sec. Note: the tape was not clear at this point, hence the first couple of lines are missing here.)
because I am leaving in the morning for Iceland and I suspect unexpurgated version of some of my ideas concerning the Ojo Caliente quadrangle. In the first place, the geologic map has been completed. I suspect that it is time now for someone to go into the quadrangle and do the geology of the area. I had to rush in places in mapping the surrounding areas at the rate of 2 to 6 square miles per day. In some places a little more detailed work might show up further features. However, I am certain that the main picture is correct and that there are sufficient details for the scale of our map. I did not get a chance to make a geologic map of that one mine that you wanted done, Dick, up north of Cerro Colorado. I suggest the possibility of further work in the area would be very useful in the southern part of the area, a detailed study of the Abiquiu stratigraphy, south of Arroyo El Rito. There are several unconformities and different lithic rock types to map, cross beds studies, etc., to give the history of the Abiquiu deposition here. Thirdly, I had no opportunity to go back and try to zone the metamorphic rocks. You will find on the geologic map numbers which are note numbers concerning rock samples I collected, most of them oriented for potential petrofabric studies that maybe some eager type around here would want to do under Ingerson's or Clabaugh's eagle eyes. I'll try to discuss the quadrangle by regions and, therefore, I hope I can record here all of the ideas before they fade away on me. My copy of my map has yet to arrive from Socorro, so I am doing this with a blank topographic quadrangle in front of me, a vivid imagination and a series of notes I had written while living in Ojo Caliente expecting to have to do this dictating now.
Central Transfer Area. - The central Precambrian area was mapped by walking the metarhyolite and amphibolite beds. These marker beds plus crossing some of the other units at occasional places gave me enough control to draw through the contacts through the entire area. You will notice that I abbreviated the symbol system on the Hopewell series rocks by leaving off the "PC" designation. There is so doggoned much data that is going to go into that little area that I suspect that we will have to use simplified notations for the Precambrian rocks. Secondly, I did not bother to transfer any of the dip and strike data or other structural data that was on the original field sheet by Jahns. I suspect that after the contacts are on and the draftsman picks out some representative dips and strikes the map is going to be so confounded cluttered already that it might be best either to refer the reader to the "on file" copy or possibly even have that few square miles around Cerro Colorado enlarged and published in an enlarged scale as a separate inset map.

The only real thing I noticed in the Precambrian area was in your note number 6 where there was a considerable amount of cordierite and, I would guess, kyanite in the metasedimentary rocks there. Otherwise I think the grade of metamorphism is constant along strike. This may be a local high or low or something and it is within the unit labeled "QPX". The Ortega quartzite seems to be uniformly within the sillimanite grade as you suggested, including the little inclusion on Cerro Colorado, in spite of what is shown on Corey's manuscript where he describes the La Madera Mountains' material as kyanite.

The little red lines in the Precambrian area are pegmatites; the blue ones, quartz dikes. Some of these are ones that I added, others were just simply copies of the ones that were on the original field map. In the northern part on Owl Cliff Tufa are three notes labeled "DFH", for D. Foster Hewett, which represents samples of the travertine that I collected for him. Those can obviously be ignored and deleted. The few places in the La Madena Mountains I could by using the cross-beds make absolutely certain that the dip and strike that I recorded on the map was right side up or, conversely, upside down. In those places I have marked little arrow with a "Y" at the end of it pointing in the direction of younging of the beds. I started a crude attempt there, in other words, to unravel the folding in the quartzite. I didn't have time to do a decent job and probably there are many more folds than are shown. I also get the impression from the appearance of the porphyrytic phase of the metarhyolite that occupies the core of Cerro Colorado that it is identical to the coarse porphyrytic granites that I have in my Brazos Peak (?) quadrangle and it is equivalent I believe to the porphyrytic phase of Barker's tusas granite. If this is true, then our
metarhyolites are post the orogeny rather than pre the orogeny as Barker has inferred, or possibly the porphyritic phase is simply not metarhyolite at all, but represents the tusas granite that has come in as sills and bodies into the same general area that the earlier metarhyolites had also intruded. I am just wondering, in other words, about our intrusive history here which might be the final answer. I thought of this too late in the game and never had a chance to go back and to field check any spots that might be critical to unravelling the history. We probably ought to discuss this with Barker, too, but I have gotten a very strong impression that the porphyritic phase at least is equivalent to Barker's tusas granite and my rocks to the north which are nearly circular in map plan, plutons that are obviously cross-cutting the earlier metasedimentary materials.

Northeast Corner. - A tremendous maze of faults can be seen in this part where it is well exposed and they probably continue farther northeast except that in the upper Cañon Seco there are very poor exposures and not much opportunity to delineate at all well. The sedimentary structures and cross-beds are well exposed in the badlands in the south half of Sections 5 and 6. The Caliente conglomerate of this region is kind of a hybrid that is all composed of quartzite debris, derived from the La Madera Mountains and therefore it is of many ages, much of it older, some of it probably even younger than the surrounding Santa Fe formation. In places you will notice on the map that I have marked the indication of the mudflow terrace deposits sitting on the old high level terraces that are between 60-68 feet in elevation.

East Side. - Santa Fe in this region is generally two segments. The lower portion is fluvial and the upper is practically all sand dune deposits and the cross-beds of the sand dunes almost invariably dip in a nearly easterly direction indicating the winds then were practically constantly westerlies during the time of formation of these dunes. One of the problems along the flanks of the high mesa there is when are you looking at dunes of Santa Fe age and when are you looking at recent cover of dunes that are apparently forming today. There is a tremendous smear of that type of thing in that area. You will notice also a very short line indicating the approximate boundary between the lower and the upper subdivisions of the Santa Fe. I made no attempt to try to map it everywhere, but you
will notice in places the Santa Fe symbol having a "D" at the end of it indicating that it was dune material. You will notice also a new symbol all over the map, a little arrow and some suffixed letters associated with it; these arrows are all cross-beds, the "X" indicates cross-bed, the "A" in Abiquiu lithology, the "D" indicating dune lithology and I think that is all, at least all that I can think of right now. It has a zone of cemented beds that may actually be a stratigraphic zone that outcrops in a pretty linear pattern, but anyway there is a suggestion by the cementation in this particular area of a fault, as shown by the dotted line and the question-marked word "fault" written along it. It may be better to leave it out completely. The terrace cap of the mesa has pumice and tuffaceous sands in the lower 1/3 of it in the southwestern part, mostly in the northeast quarter of Section 19. The notes on the gross stratigraphy of the terrace cap in that area is shown on the map. This pumice material has left a (Secretary's note: the tape was not clear at this point and I believe there is a phrase left out).... bag from both of the two outcrop areas sampled, only the sample 16 has good pumice fragments. I wonder if they are from the great Jemez caldera. (Sec. Note: a phrase is missing here).... also have come from No Agua Mountain which is north of Tres Piedras which is the only other locality that I know of that has pumice and rhyolitic material of that late geologic age. Anyway, it adds a little spot for study, research and correlation and we can have a grand time with it or ignore it.

Southeast Corner.- The southeast corner was quite frustrating because there is a recent dune cover over everything and therefore virtually nothing to see. Arroyo Gavilan has a tremendously soft sand bottom, so I doubt if it would be passable for even a four-wheel drive vehicle. The cross-beds in the Abiquiu formation in the southeast and eastern belt, as you can see, are generally south to southwest. Quite a contrast to the cross-beds over in the western side of the area which generally trend south to southeast. It may be that these represent streams that were coming from the north because the Abiquiu is equivalent to the Cordito member of the Los Pinos formation and that must have been derived from the north, so these streams then were probably filling the fans in around Cerro Colorado accounting for a cross-bed preference slightly toward the center of the map area instead of straight due south. It is possible to drive to the old abandoned windmill shown just south of Arroyo Gavilan over by the east corner of the map. I don't think you could cross the arroyo and drive on northward and get in any closer to the terrace mesa in that portion. You can't get on to the high mesa from
29 July 1960
Dr. Richard H. Jahns
Page Four

the east side because of a continuous fence. Incidentally, about a half mile east of the sheet is a high flat-top of basalt capped peak that is a very intriguing looking thing. Even though I walked on the east and south flanks where sandstones, tuffaceous sands, and volcanic bearing conglomerates are found in nice bedded layers that are dipping inward under the cap, with the cap itself of a basalt the likes of which I don't recognize because it is not at all like the Hinsdale flows that form the big mesa cap a few miles farther to the north and east. Those flows are quite coarse grained and holocrystalline. The basalt capping the little peak is very fine-grained and dense and an olivine basalt. It may be events, on the other hand, it may simply be outlying remnants of basalt of unknown, as yet, source area.

Northwest corner and west side. - This is one of the most monotonous areas in the entire quadrangle--practically no exposures, most of it appears to be not only of Santa Fe, but of dune type Santa Fe. The upper surfaces of the long ridges are probably graded, but there is no real harmony to them today because of the later erosion. There is a thin gravel veneer on some of it and the gravel itself suggested that it was set down from the original terrace surfaces. The fault north of State 96 is well located in a few places as indicated by virtually a solid line, the rest of it is dashed because of its approximate location. The fault must die out very shortly south of the highway, although the exact spot I don't know. The exposures, again, are kind of poor. Incidentally, about a 100 yards west of the north-west corner, going out that little crummy road that shows up on the map is a tremendous outcrop of Precambrian quartzite, just barely missed the map, fortunately, or we would have had another gloop of color up there.

Area south of Arroyo El Rito and Cerro Negro. - This is the most fascinating portion of the post Precambrian outcrop areas. Unfortunately I was a little pressed for time and spent only three days field work in the whole area. It deserves more time to do the details of the Abiquiu stratigraphy and to study the sedimentary and volcanic history that is so well exposed in it. The area that you have on the map marked as "giant scour and fill structures" is actually a little outlying remnant of a spectacular unconformity within the Abiquiu formation. The best exposures of the unconformity are along that cliff face and surrounding the area labeled "Tba". That area includes the flows and flow remnants, volcanic
29 July 1960
Dr. Richard H. Jahns
Page Five

breccias, agglomerates, and assorted volcanic junk that represents to me a moving, flowing mass of volcanic material filling a giant channel. That material, as you can see from the dip and strike data, is strikingly unconformable on the older Abiquiu that has been folded and then maybe possibly even faulted in a few places. It has been doubled in this big channel area. It was then filled with the volcanic material, probably in part from Cerro Negro, but also from the dikes that are seen cropping out in this region. So the stratigraphy appears to be this within the Abiquiu sequence here: a lower, purplish sand and silt (this is best seen in the northeast quarter of Section 28); these are overlain by a green and brown sandstone; then, there was an interval of folding and erosion; then this volcanic activity; and, then, unconformably across those, the unit marked "Post-Tba". Now, this "Post-Tba" starts with brown sands and silts that are really just a thin lower unit and they are immediately overlain again by purplish colored conglomerates composed of volcanic material that is typical of the Abiquiu of this area. East of the north-trending fault and east of the outcropped area of "Tba", the stratigraphic column is a little bit different wherein it has a brown sandstone that is between purplish colored silts, sands, and conglomerates. This brown sand unit thins eastward very rapidly. The suggestion I make at the moment is that the unconformity on top of the brown unit is probably the same unconformity as the one on top of the "Tba". Some of this area I was mapping during a blinding rain with the result that all of the major features are right, but that somebody probably ought to check the strike directions of some of the dip and strike data along say the middle of Section 35 and 34 in that region south of Arroyo El Rito. A lot of those dips and strikes were eyeballed in from a distance that gets the dip, amount, and approximate direction and put down the approximate strike just by eye onto the map. The two major fault zones that you can see here, the one that would then pass west of Cerro Negro and up around Cerro Colorado and the one then passes into the Ojo Caliente valley apparently trend on to the southwest into the Medanales quadrangle where they seem to be the equivalents of the big cemented walls of fault material that are down there in the southern part of that quadrangle.

General comments on Abiquiu, Santa Fe stratigraphy. - The contact between the Santa Fe and Abiquiu is a little problem in places because of the inter-bedding of the two types of lithology. In particular, northeast of Ojo Caliente where I first started, you will find a unit marked "TAS" Abiquiu-Santa Fe inter-bedded which I started to map and then decided that this was ridiculous; I will pick the contact where Santa Fe lithology above it is virtually 100% of
29 July 1960
Dr. Richard H. Johns
Page Six

the section. There may be in places one or two thin beds, each a few feet thick above that contact line. Below it, I have left all of the inter-bedded material in as just part of the transition zone, then, between the Abiquiu and the Santa Fe. In other places, there is a very sharp, clear-cut break between Abiquiu lithology and Santa Fe lithology. In particular the area west of the northern part of Arroyo El Rito which is well shown there were I have the contact drawn. I have a good picture, incidentally, of that area in the northwest quarter of Section 8, Township 24 N, Range 8 East, that probably would be easily converted to black and white and be an illustration in the report.

Faults. - Faults are of at least two ages within this area. The faults that break the Precambrian, many of them are also pre-Caliente conglomerates. The best exposure of that is in the new roadcuts south of the bridge in Section 1, north of Ojo Caliente, where metarhyolite is faulted against the quartz micablite schists and the fault itself in both of these units is buried by a thin veneer there on Caliente conglomerates. The other systems of faults are obviously post-Santa Fe and pre the high terraces that are at least 700 feet above the present stream level. Those terraces are not faulted as shown in several places, the best one being up northeast of Ojo Caliente in Sections 5 and 6.

Miscellaneous Items. - How about the possibility that the oldest high terraces are equivalent of the Ancha formation of Baldwin?

You asked me to see what I could do with that long ridge north of Cerro Colorado and whether I could pull through some of the Precambrian units there. I am convinced that the ridge itself is composed of residual detritus that may, in part, have been Caliente conglomerates, but, anyway, it certainly has a mappable cap of unconsolidated materials today. By fighting along that steep back slope along the fault zone, I found contacts of some of the Precambrian units there that crudely coincide with the ones that we can trace so well to the east. So, it is, at least in part now, broken down and subdivided.

I gave the cross sections a brief looking over and as far as I can see they are all drawn correctly. I suspect that they will have to be redrafted again to fit the new scale; maybe not redrafted, but at least they could probably photographically reduce them to the new scale and then have the topography corrected slightly and I suspect that they are all ready to go.
TUSAS MOUNTAINS
AND ADJACENT GEOMORPHIC UNITS
IN NEW MEXICO AND COLORADO

EXPLANATION
- Mountains and Hills
- Taos Plateau & Costilla Plains
- Re-entrants of Rio Grande Depression
- Alamosa Basin
- Upper Chama Valley

Scale in Miles: 5 10 15 20 25 30

Boundaries: Undetermined
Figure 8 - Generalized section in the eastern part of the Tugas-Tres Piedras area. To show the stratigraphy, sediments eliminated and present surface is assumed to be essentially horizontal. Relief is diagrammatic.
Figure 9 - Diagrammatic correlation chart of the Tertiary rocks of the Tusas-Tres Piedras area, New Mexico. Relationships between the Hinsdale formations are not shown. Chart is not to scale.
Figure 21- Diagrammatic section across the Taos Plateau from the Tusas Mountains on the west to the Sangre de Cristo Range on the east. The diagram shows the inferred relation of the Servilleta to the Los Pinos formation and to the Sangre de Cristo Range and the inferred intertonguing of basalt and gravel and the asymmetry of the basin of accumulation.
Figure 25- Map of the principal faults of the Tusas-Tres Piedras area, New Mexico. Numbers refer to localities discussed in the text.
Figure 27 - Block diagram of the Tusas fault zone in T3.27 and 28 N, R5 8 and 9 E. Los Pinos formation. Position of the diagram is indicated by box on the fault map.
Figure 28 - Section in the southern part of T21N, R9C, and across the north end of the Petaca Mesas illustrating two periods of movement on the same fault. This fault constitutes the Tusas fault zone at this point.
GEOLOGIC MAP OF THE TUSAS-TRES PIEDRAS AREA NEW MEXICO

EXPLANATION

QUATERNARY

Oal
Olb
Oog
(Alluvium: Oal: landslide, Olb: shown only where deposits obscure older rocks; sand, partly alluvial, and gravel, Oog)

EROSION SURFACE

Servilleta formation
(basalt and interbedded gravel of the Taos Plateau)

EROSION SURFACE

Dorado basalt
(quartz-basalt; local flows)

EROSION SURFACE

Cisneros basalt
(widely distributed, disconnected flows)

EROSION SURFACE

Tertiary

Cordito member
(tuffaceous sandstone, conglomerate of rhyolite fragments, rhyolite flows and breccia, intrusive rhyolite pipes, Tfp)

San Antonio Andesite
(Hypersthene-andesite of San Antonio Peak and other areas; relative age uncertain)

EROSION SURFACE

Jarita basalt member
(basalt and hypersthene-basalt, Tfj)

Esquipul member
(tuffaceous sandstone, tuff and conglomerate of coarse pyroclastic lapilli-andesite fragments, Tfp, Tfb)

Biscaro member
(tuffaceous sandstone interbedded with conglomerate and breccia of andesite and andesite-lapilli fragments; rhyolite tuff and breccia; dikes and pipes of intrusive andesite-lapilli and rhyolite, Tbi)

EROSION SURFACE (?)

Treasure Mountain formation
(rhyolite and quartz-lapilli tuff, sandstone, and conglomerate of volcanic fragments and rhyolite flows, Tpt; at top welded rhyolite tuff, Tptc)

Los Pinos formation
(stream-laid sandstone and conglomerate of volcanic fragments, and tuff; andesite lava flows; Tfp, Ib)

Conejos formation
(andesite and andesite-lapilli breccia and flows interbedded with tuff; subordinately sandstone and conglomerate)

EROSION SURFACE

Per-Cambrian rocks
(undifferentiated igneous and metamorphic rocks)

SCALE IN MILES