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

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by

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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 vulcanism. 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 Servilleta 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 Servilleta 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, [illegible] 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 strati-graphically 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 re-presented 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

p.5 "The principal results of the investigation of the Tertiary geology in the Tusas - 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

6 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 Servilleta, 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 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.

[illegible] Conejos formation — [illegible]

23 ~~[illegible]~~ Lithology — dark-colored quartz latite breccia characteristic unit. Also includes unbrecciated lava flows, tuff-breccia, agglomerate, and some fluviatile beds, which range from tuffaceous graywacke to poorly sorted conglomerate. Breccia and flows are generally more abundant in the

24 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, tridymite latite and basalt also occur. Tuffs tend to be felsic, and the conglomerates are formed of pebbles and boulders of mixed types, in which dark-colored lavas predominate.

25 gy & gy-gn brec. tend break around the frags, but the more felsic, purp-gy to red pur brec break across frags.

In composition the flow rocks range from basalt or olivine latite to quartz latite, and the breccias from olivine latite to quartz latite.

darker rx = plag, dk gn pyr, iddingsite after olivine are common pheno. Bio rare.
lighter = plag, bio, alt. Hb in variegated brec: rare elsewhere.

26 tuffs well-indurated mineral grains & ang peb in fine-grained matrix
grade laterally to tuff-brec or agglom, the matrix of which resembles the tuffs
larger frags ang to rndd cob & peb to 4' diam.
No sorting, no bedding, develop spires & pinnacles.

Thickness — base not exposed at thickest point in Los Pinos Canyon 2 mi. W of east[illegible] R.6E = 1000', elsewhere will wedge out completely against p€

Origin — chaotic assemblage of clastic & effusive rocks.

27 massiveness, indistinct bedding, poor sorting of material, 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 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

mere accidents mechanism

p.28. some probably mudflows
some pyroclastics channeled by streams & backfilled by alluvial deposits

p.29 – Presumed Conejo under Treasure Mountain fm. in Tusas Valley correlated
1. volcanic activity suggested by water-laid tuff
2. resemblance between bentonitic arkose & matrix of Conejo agg in Rio San Antonio Valley
3. stratigraphic position
4. presence of considerable non-volcanic material in Conejo in vicinity of Brazos Canyon
5. similarity of between these rx & beds under volc pt. of fm in Summitville quad. Colo.

p.30 <u>Treasure Mountain formation</u> – instead of T.M. quartz latite of Cross & Larsen

Distribution and relation to older rocks.
disconf. on Conejo well exposed E side of small valley N of Los Pinos R in Sec. 33, T32N R7E. relief on top Conejo to 300'.
p31 1 mi S of San Miguel, top bed of T.M. abuts against slope of Conejo.
canyon topog found in Colorado bet. these fm generally lacking.
many places T.M. overlaps Conejo & rests on p€.

Lithology – rhyo & qtz latite lava, welded tuff & tuff breccia, & intergrading tuff, graywacke, and cg
sec. 2, p. 93 – upper ½ flow, lower half tuff
n. side Rio San Antonio upper strata mostly flow.
15 mi. SE – tuff more abun.
flow or flow-like rx confined to base of fm. because of topog sometimes missing.
distinctive bed "welded tuff" marker at top.

flow-like rx at base may be welded tuffs – dk gy to blk vit.
32. porphy qtz lat. overlain by flows of similar comp. dull brn to red color, more abun porph than blk rx & aphan. pheno – plag & bio.
true flows more persistent than blk flow-like rx.

capping welded rhyolite-latite tuff 25' thick weathers into coarse slabby frags
‖ to top of bed. commonly lt gy at many places grades from gy at top through pur-gy to red at btm [illegible] fine gnd aphs, porph
tab plag, bio, rare pum[illegible]
under [illegible] groundmass [illegible] little frags, shard devit [illegible]
fused together some [illegible]

p.33. welded tuff [illegible] thick in [illegible] SE corner [illegible]
thins W & S so that along highland W of Beaver Creek & N. Tusas Valley
5-15' thick. Pinches out N of S limit of fm.
Covered 160 sq. mi. in N. Mex. + large area in Colorado.
many places reaches 10' pink to buff, massive but friable, felsitic tuff
good exp 1.2 mi. SE Sublette sec house on D&R.G.
contact undulatory w/ involution of underlying bed into the welded tuff.
34. Billow welded tuff bulk of section is tuff & tuff-breccia, tuff arks, ss, cg
intergrade, mid pt. tuff & flow interbedded.
in Beaver Creek a decrepitating bentonitic pink tuff - nr. base of fm.
Cañada Biscara has bed strat. higher similarly altered -
35 finer-grained clastics ∠ - sub∠, cob & bldrs sub∠ - well rnd & water-worn
cg bed 1-15'
dk. colored felsite or and predom. ang volc rx of cg.
welded-tuff at top only way to distinguish from overlying Los Pinos fm.
in so. pt. unsurveyed T31N R6E & along E side Tusas Valley a consid. pptn
peb & sones beds nearly all derived from p€ rx of nearby hills.
Some beds in p€ are breccias of hillside rubble
Thickness - 320' on N side Los Pinos to 60' nr. S. limit of step.
36 Origin - accum. normal airborne tuff, welded tuff, possible flows, and
water-laid volc. tuff & cg. Lacks steep initial dips & abrupt changes in
lith. of Conejos gp., gen. even bedded so that individual beds can be traced wel
center or centers volc. act. farther from N. Mex than prev. Conejos.
lenses of coarse cg in beds fine-grnd tuff suggest powerful streams that
were graded for their loads & alter. scoured & filled their channels.
37. welded tuff is lithoidal, mostly massive & unlayered except for locally
vitreous base, rather uniformly fine-grained
in compo. & aspect similar to welded tuffs in Idaho; Bishop, Calif, "ignimbrite"
of New Zealand.
in comp, text, size similar unwelded tuff of Valley 10,000 smokes, Katmai.
37-40 long comparison w/ other tuffs as to origin
T.M. - well sorted, uniform fine grn. pebb never airborne, never covered higher hills
foreign rock present only locally [illegible] of upper tuff over lower
ave. thickness [illegible] might distrib. like pumice
flows of Mazama [illegible]

p.41 - Significance – most clearly ...
allows distinction bet. Conejos & similar Los Pinos fm.

42 - Age of Potosi rx – overlie Burns latite of Silverton volc. series & underlies Creede fm (Cross & Larsen, 1935, pp 51-53). Both Burns & Creede carry Miocene plants (Knowlton, 1922; pp 185-192.

Petrography of Conejos –
rather completely studied by Cross & Larsen 1935
Larsen, Irving, Gonyer, Larsen III (1936-1938)

p.45 - Los Pinos formation

atwood & Mather – gravel fm on San Juan peneplain & underlying Hinsdale
type locality in vicinity of San Miguel ~600'
scattered dsps mainly ss & cg, ~ $\frac{1}{4}$ fm tuff & tuff rx.
Cross & Larsen included in Hinsdale.

46 Butler retains main here & uses as fm. Sep. by uncomf from Hinsdale.

Distribution – most widely distrib. unit in map area.
atwood & Mather – present in vicin of Brazos Canyon
Some of rx E of El Rito Creek mapped as abiquiu by Smith prob. Los Pinos
pt. if not all of abiquiu is equiv. & pt. of Los Pinos fm.

47, distinction bet. 2 fm. diff. to make, abiquiu may be abandoned

Subdivisions – not uniform laterally or vertically.
S. of Broke Off Mtn – fm into 4 mem – (1) 3 mem disting from each other by domin. kinds of rk frag consist largely of water-laid graywacke, cg, breccia w/ minor am'ts of tuff & volc. breccia, (2) mem basaltic lava.
N of Broke Off zonation not marked – undivided gravel = "Los Pinos gravel" of atwood & Mather = 2 lowest mem. to S.; upper basalt.

S. of T.30 N & W. of Tusas Creek is shown as undivided – 3 clastic members are present, not enough time to map.

48 - "In the vicinity of the Petaca Mesas the top member of the formation grades laterally from water-laid volcanic gravel and pyroclastic rocks to arkosic sandstone and sandstone that are continuous with the Santa Fe formation of the abiquiu quadrangle."

Mag. of changes in strat from E to W across Tusas Mtns appear to be less than the changes from ...

p.48 - Undivided gravel member — strat. section ✓ of Rio San Antonio (p.13)

49, lithology - predom graywacke, tuffaceous graywacke, fine-grained cg.
more syst. vert. distrib., more tuff near bottom. relat. persist.
cg zone ~100' below top,

generalized strat section in NC T30N R7E n. of Rio San Antonio =

Jarita basalt member	50'
Undivided Los Pinos	
Not exposed, probably fine-grained fluviatile beds	50'
Greenish brown, indurated sandy graywacke & cg cemented by chalcedony; cliff forming	50'
Conglomerate and interbedded graywacke or tuffaceous ss; typ. boulder littered slopes	250'
Tuffaceous siltstone, fine-grained & tuffaceous graywacke; may include some tuff	150'
Conglomerate of angular, dark-colored, andesite-like fragments in a matrix of tuffaceous graywacke	100'
Total undivided Los Pinos	600'
Treasure Mountain fm. - not measured	

50 (margin, beside the conglomerate/graywacke entry)

tuffs are felsic, <r min grains in frag matrix partly devitrified glass,
small <r peb uniformly distrib. thru some beds.
color commonly light gry, but range from light buff & cream white.
poorly sorted ss gywke uniform distrib thru entire fm. grades to ss tuff silt
or gywke-cg. lt gry, some lt buff, lt. brn. beds ¼"-6" flew 1'.
51 - x-bedding common. <r grns fel, qtz, bio main constit. of ss-gywke
some pyx, hb, mag gen. present. Presence grns w/ good cl. suggest
short transport - few 10's miles,

cg litters surface - residual rubble. cg beds 1' less, max 10'
lenses & pockets common. sorting rela. good.
thicker beds peb-cob 4" in diam.
larger bldrs to 4' generally in beds to 2x largest phenoclasts.
in gen, smaller frags subang, less well rnd than larger.
52 along Rio San Antonio lower cg <r, those 200' above base more rndd

p.52 – phenoclasts mostly volc rx. mainly intermed- felsites.
Many dk-col and-like peb resemble both rx of underlying Conejos &
of Biscara mem. Partic. abun. in lower pt. present thru all.
bldrs & cob gy-maroon cse porph fel 1.5cm pheno. fel are common,
these peb in channel fillings – unlike any other rx in area or Conejos quad.
53 – NO peb. of Treas. Mtn. rx found in Los Pinos fm, even close to contact!

Biscara member – type Cañada Biscara T29N R8E
character by abun of phenoclasts of gen dk-colored qtz latite breccias & cg
probably correlative w/ pt. of Smith's Abiquiu tuff

55 – can be subdivided into 3 pts distinguished by rel. abun. of
56 dk-col qtz lat, rhyo, pC rx in coarser beds.
| lge am't tuff, some brec., common in lower pt, some peb in mid pt.
abun, predom. in upper pt. volc brec. & cg.
close to pC hills basal members are unassorted jumble of frags.
57. some arkosic beds
similar to lower Abiquiu tuff
58 – dk col latite – lt gy-gn to mar-gy & blk.
all porph, finely x-line to aph
plag, shiny small hb common pheno.
iddingsite after olivine gives rust-spotting
59 pale gn spots common – prob altered pyx.
bio present in some.
pebbles of these rare strat. above Biscara.
rhyo breccia 70' in SE Dorado Canyon. blue-gy aph rl
also small dikes & plugs in this member

61 Esquibel member – characterized by the abundance of peb, cob, bldrs
of conspic porph qtz latite
recog into west pt. R.7E.
62 similar in lith to undiv Los Pinos N of Broke Off Mtn.
→ gy or pur-pink qtz latite w/ conspic. fel pheno to 8 mm
bio hb pheno also pres
transitional into underlying Esquibel member

65 - Esquibel mem laps unconf around hills of pC rx.
believed to be correl of large pt of undivid Los Pinos of N pt. of area.

Jarita basalt member -

66 some of basalt interbedded w/ tuff in Abiquiu quad prob. correlative

67. 1. northern type a.- fine, slightly porph, mod vesic, rusty iddings
chal amyg - - more common, on bottom if both present
b. - fine, more porph olio, no inter pore space,
irreg vein $CaCO_3$, $CaCO_3$ amyg, pheno pyr

68 2. southern type - basalt, small irreg pale gn or yel-gn spots
superf. alt. of plag. gives moldy look.
sparse pheno of hyp, - inter pore space
dense type w/ rusty idding, plag.
dk gn pyr than ol inconspic.

69 3. central type - fine-gnd, porph, abun. irreg. vesicle.
tab plag 2-5 mm. rusty iddings
some flows w/ sparse qtz & dk gn pyr.

thickness to 100'

70. - Cordito member

71 - predom rhyo, largely flow beds fine-gnd mudstone & cse cg
w/ minor but imp. tuff & lava

72 cg frags = 1. rhyolitic rx - sparse to abun porph. wh, red, pur, blue, gy
qtz, sani, olig
2. porph rx - coarse, feldspar 0.5-1.0 cm. to 2.0 cm.
rhyo or qtz lat.
some bio, hb, qtz. aph matrix

77 Erosional interval preceding the Cordito member is apparently of only local significance.

few small dikes & plugs of pur-pink rhy of this age

No Agua Mountain rhyolite - eroded remnant of rhy vol of Los Pinos

78 thickness of Los Pinos - thickest in N pt. T28N - Biscara 450' + Esq. 650

79 Cordito 250' to 600' Max thick 1700'
600-700 Los Pinos [illegible] [illegible] in Brazos R.

p.81 – Origin – these descrip. do not fit concept of Atwood & Mather who believed was pt. of alluvial apron from renewed uplift of San Juan Mtns.

There is no tangible evidence that alluvial beds are result of older volcanic terrane.

Charact. pertinent to origin: 1. lava flows, breccias & tuffs interb w/ alluvial dep

2. many of types of rx in gravel petrog. similar to interbed eruptives

3. kind of pebbles changes systematically from one member to another

4. many of the larger frags in cg differ from pre-Los Pinos volc rx of

82 San Juan Mtns. that crop out w/in a distance from which such large frags could be transported

5. changes in lith of fm more marked from N & S than W to E.

1 & 2 indicate much of material from active volc. centers

3 is change in eruptive character of rx or change in locus of eruption undivided pt. from multiple sources.

4 Conejos buried by Tusas Mtns for at least 20 mi to NW. ∴ dk-color clastic from other source.

83 biggest boulders in Rio San Antonio not Los Pinos R. 5-9' diam.

84 5 undiff Los Pinos, stream sources different from those dep. Bis, Esq. Cordito change in lith must be result streams travelling 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 Tusas quad 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 NE source of Los Pinos =

1. all data points to east source for Santa Fe

2. Jarita basalt from vents in E pt. or E of mapped area.

∴ surface sloped W or SW.

all known vents of younger basalts, etc in Brazos Canyon are on E of Tusas Mtns

Taos plateau has obviously been an area of eruption during a long period.

Angularity of frags + prox. of p€ frags to steps indicate local origin.

87. many places volc rx against p€ w/o intervening debris.

fresh arkose + absence colored clayey matrix in bed from p€ suggests relatively dry climate.

Section 1. Conejos formation on north side of the Los Pinos River in NW¼ sec 31, T32N R7E

Conejo formation

Quartz latite breccia, gray-green, probably near rhyolite in composition	100'+
Qtz lat massive & brec. flows, pur-pink to pur-gy, pheno of plag, bio, sparse clinopyx in aph groundmass; frag & matrix closely similar	210
Qtz lat, gy-gn & gy, nr andesite in comp, interbedded aggl & br	55
Qtz lat, nr. and in comp, in pt. olivine latite, dk greenish gy porph rk, some plag & rusty iddings after oliv, interbed agg, br & flow	40
Qtz latite, mostly gy & gy-grn br alternating & interbedded w/ olive drab flow & breccia prob. oliv lat, locally rk bleached white by alteration, which includes silicification	60+
Agglomerate w/ lge rounded frags in tuff matrix, interb tuff & tuff ss, mostly gy to gy-grn, fills channels in underlying rk	10-65

93 Local unconformity ———

Qtz lat pyro br, pastel gy-gn to pale maroon frags in lt. maroon gy matrix, pheno shiny blk hb, plag, sparse bi in aph groundmass	105-50
Brec & agg of lge random frags in tuff matrix, gy-buff & grnsh gy	35
Tuffaceous ss or graywacke, gray	5
Not exposed to level of Los Pinos River	55
Total thickness measured	675+

Vertical range of exposure: 765, dips are irregular in direction and amount

p. 15. Section 2. Treasure Mountain formation on north side of Los Pinos River,
sec. 33, T. 32N., R.7E.

Treasure Mountain formation, top

Welded tuff of quartz latite, gray to pink, massive	58
Tuff, pink, friable – general resemblance to overlying welded tuff	5
Graywacke cg, lge cob cg, & gywcke, interb; bds lge cob cg 8' thick	61
Tuff, buff, felsic overlies fine-grained gy felsic tuff	16
Sandstone, buff, fine-grained, tuffaceous	9
94 Cobble cg, well-cemented overlies gy sandy cg	4
Tuff & tuff-br, felsic, gy to buff, interb, carries 5' bed of cg in mid	50
Poorly exposed, mostly gy tuff & tuff-breccia, some interb water-laid gywcke & cg	50
Rhyolitic tuff or tuff-br, massive, elsewhere but not in this section closely assoc. w/ brn, olive-brn or red-brn flows of rhyo	15
Total Treasure Mountain	275

Conejos formation

Olivine latite, gy, gn flecked, massive somewhat porph, pheno of dk gn pyr, plag, oliv & iddingsite after oliv — not measured

Section 5, [illegible] formation near southwest corner of exposure,
sec. 15, T. 28 N., R. 8 E.

Top not exposed, indefinite, probably consist of cg of ∠ to sub∠ frag of p€	not measured
Tuff, felsic, pk, friable, carried chalky frags of pumice & bio flakes	10
Ss, tuffaceous, & ss cg of frags of p€ rk	20
Tuff, fragmental, wd, gy-brn, chalky frag of pumice, grains of fel & bio	20
95 Rhyolite flow, olive brn, slightly porph, pheno fel & bio in aph grndmss	20
No exposure, prob cg of frags of p€	not measured
Total measured thickness	70

Section 4. [illegible]
sec. 5, T. 30 N., R. 7 E.

Erosion surface

Santa basalt member, 3 flows or flow units	40
Undivided gravel member	
Sedimentary beds, not exposed	125
SS & cg, interb, well-ind, cem by chalc-SiO$_2$, some ss-argillite at bot	50
Gywke, tuffa, lt brn to gy, well-bdd, partly ind; tuffa-ss, & grav-tuff	110
Cg & ss-cg of mixed frags dk-colored qtz lat & cdly porph qtz lat frag	10
Tuff, water-laid, massive & thin-bdd, inter-bdd thin lenses tuffa cg-gywke	65
Cg, tuffa, small-peb, & tuffa gywke	
96 Tuff, peb, mass, poor bdd, bds qtz lat cg bldrs to 2' diam	60
Cg, lge cob, mostly dk col qtz lat, poorly sorted peb cg & tuffa gywke in upper pt	15
Cg, sm. peb, ∠ dk-col. qtz lat, grades up to tuffa gywke, scattered lnses, peb, bldrs, some thin bds cg, ∠ small peb	32
Tuff, some lenses of cg of conspic. porph frags of qtz lat	30
Silt, tuffa, well-bdd, & fine-grnd tuffa gywke	15
Rhyolite tuff-breccia, prom. frag of pumice	20
Tuff or tuffa gywke, well-bdd, gy, some thin beds w/ pumice frag	12
	13
Total thickness measured	597

96 - Section 5. Composite section of [illegible] part of the Cordito member, the Jarita basalt member, and part of the Biscara member of the Los Pinos formation on the east side of Tusas Creek, sec. 19, 29, T.27N., R.9E.

Cordito member

Covered slope, top not exposed	not measured
Sandstone, friable, partly tuffaceous, buff, poorly exposed	55
97 SS, well-ind, muddy, lt brn, w/ local lenses of cg in upper 1/3, mostly frags rhyo, some qtz lat & basalt	33
Poorly exposed, prob. friable lt brn ss w/ local lenses of cg	22
Cg lenses, sub <1 frags rhyo in matrix of muddy sand, local beds of muddy ss	10
Cg, tuffa, gy of <1 peb of rhyo & some scoria bas	9
Not exposed	9
Tuff, mottled white, pk, & brn, grading to underlying beds, poorly exp	18
Ss, arkosic, cream gy, tuffa at top w/ white frags decomp glass ~~at top,~~ in upper pt, arkosic w/ conspic flakes of musc slightly cg in lower pt, poorly exp toward top & bot	37
Total Cordito member measured	193

Jarita basalt member

One-2 basaltic flows, some cg	14-49

Biscara member

Cg of frags pt rx prob. top Esquibel mem but mapped as Biscara	18
Local unconformity	
Cg, tuffa, frags dk col qtz lat, some frag coly porph rk, poorly exp	37
Tuff & peb tuff, pinkish wh, rhyo, mixed w/ gravelly qtz lat tuff & tuff br; dips steep & irregular	87
Base not exposed	
Total Biscara & Jarita members	158
Total thickness measured	351

p.149
150 Table 3 — Treasure Mountain welded tuff from NE corner unsurveyed T.30N., R.6E., 1 mi S. of big bend on Rio San Antonio, 7 miles west of San Antone ranger station; analysis by J.G. Fairchild

Analysis		Norm		Modes	
SiO_2	75.79	Q	41.94	qtz	—
Al_2O_3	11.63	or	20.57	Orth	trace
Fe_2O_3	1.99	ab	23.58	Plag	20 (An_{30})
FeO	0.25	an	8.34	Aug	trace
MgO	0.49	C	.20	Oliv	—
CaO	1.70	di	—	Bio	2
Na_2O	2.76	hy	1.20	Mag	—
K_2O	3.47	ol	—	Groundmass	77
H_2O^-	0.46	mt	—		
H_2O^+	0.73	il	.61		
TiO_2	0.35	hm	.61		
P_2O_5	trace	ap	—		
MnO	0.04				
Sum	99.66				

(from Wells, 1937, p.35, Col. BB)

(from E.S. Larsen, unpub manuscript)

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STRUCTURE

General statement

area in transition zone. N & NW dome arched up & dissected = San Juan Mtns
E & S depression of structural trough w/ ext Pleist erosion =
relat. low plateaus & valleys of Rio Grande Depression
In this area, rx also deformed & main geomorphic features are expression of the larger structural elements somewhat modified by erosion
pЄ structure not studied. However, structure of Tert rx represent lesser features superimposed on a larger block that is composed of pre-Tert, chiefly pЄ rx. W. pt. of Tusas Mtns marks line of culmination of a major uplift of which structure has not been completely worked out.
152 This tilted block ends along W. ft Sangre de Cristo where pre-Tert rx abruptly uplifted, prob. by normal faulting,
w/in Tusas-Tres Piedras area the def. of Tert rx consists of general eastward tilting & mod. displacement on a group of related normal faults

Structure of the area proper

Tilting = dip 4-6° east. locally near faults to 25-30°
reversals nr. dips usually WSW in direction of downthrow
Conejos has local dips < 6° - initial dips of coe-gnd pyroc rx
153 basalts younger than Los Pinos rarely < 3°
Tres Piedras north gen strike N15-30W
South more northerly
154 Original dip of Los Pinos from NW to SE. Today other direction

Faults = partial en echelon arrangement into 2 fault zones - Tusas & Vallecitos fault zone.
2 sets but part of 1 system.
"main faults" - longer, trend w/ general strike of the fault-zones,
155 "cross faults" - shorter, transfer displacement from one main fault to another & are an integral part of system
Criteria of faulting - rarely exp; abrupt repetition of strata & displacement of distinctive beds, Petaca Mesa - eroded fault scarp
silicification in Santa Fe beds - dip 65°W
Elsewhere only planes of minor faults ⊥ to main faults measured
dip 70-80° NW or SE

p.155 Tusas [illegible] zone - 44 mi in [illegible] & [illegible] S
156 Single fault or 2-3 sub ǁ faults.
max. width zone 3 mi.
Petaca Mesas N - N25-30W trend to zone
1 mi. S. Servilleta Plaza 67°W dip
nr. mid sec 24, T28N R8E, 77°WNW dip on small fault
157 Almost w/o exception the west side of main faults is downthrown
Small graben 1.25 mi. N of Servilleta Plaza.
main faults not persistent along strike - die out or abruptly offset by X-fau[lts]
Petaca Mesas - 10 mi. long.
Some branch into 2 faults that continue for miles;
others branch & die out.
block diag fig. 27 shows en ech w/ X faults
strike faults
158 because relat. steep dip, strike faults, strat. throw ≈ dip slip.
displacements noted marked on fig. 27
159 X. faults gen N 40-65°E
2 types X-faults recog: 1= those that offset or transfer displacement on main faults from 1 to a[nother]
2. those which do not appear to affect the position of the main faults.
only a few of these have been map.
2, 3, 4 on fig 27 important X-faults. cause drainage changes
N side down
5, 6 - type 2 X-faults. either side down
160 type 1 do not cross main faults
fracturing rather than bending of strata
Valleatos fault zone = only partially mapped
at least 2 main faults & related X-faults N40W trend in map area
E of N in Abiquiu quad
161 incomplete data, combined displacement 1600' max, 1200' min.
Other faults = 8, 9, 10, 11 lie outside Tusas fault zone & independent
7 branches NW from Tusas fault zone 1 mi W. Broke Off Mtn,
~~strike~~
no. 10 passes into 2 en echelon monoclines at S. end.
show well on Santa [illegible] monoclined mesa bet. Rio San Antonio &
Los Pinos R
Strike N20-25W similar to Tusas fault zone [illegible] displacement less to 200'

1-162 - Two periods of movement on faults = All known faults are younger than Los Pinos fm. prob. younger than Santa Fe & pre-Dorado basalt.
2nd movement after Dorado & possibly after Servilleta basalt also.
Post-Servilleta faulting is inferred only from topo exp. at one place east of Comanche Canyon in T. 26 N., R. 10 E. & on general evidence of def. of fm.

163 2nd movement not present on some faults.
½ mi E. D&RG pumping sta in Los Pinos R. canyon ffpits Santa, Servilleta undist.
164 Petaca Mesas. show 2 deform. well.
fault 9 - 2 displ. 40' pre-Cisneros 20' post
165 renewal of faulting general rather than local cause.
pre-Serv faulting caused locus & condit. of Servilleta to be distinctly diff from those that prevailed during the deposition of the Los Pinos & older.

Age of deformation =
pЄ & post Los Pinos only deformations w/ visible record in this area.
deformed Cret rx to W., in Colo, Sangre de Cristo = Laramide?
∴ early Tert - renewed tect. movements → basins for terrest depos.
pre-volcanic Tert. { Blanco Basin on beveled Cret.
Vallejo fm. - Eo or Oligo in N.E. Rio Grande Dep (upson)
El Rito fm Eocene(?)
164 Picuris ~~tuff~~ }
probably uplift & erosion to pЄ in this area
no evidence of def. between Potosi & Los Pinos as inferred by Atwood & Mather
San Juan peneplain probably post-Los Pinos.
accum. of basin deposits (Santa Fe, Los Pinos) implies some deformation
167 - 1st episode Tert def. recorded post. Santa Fe or late Pliocene
interval of erosion, extrusion of Cisneros & Dorado bas.
2nd episode post those ↗ exact age not known.
suff. time to reduce 500' relief caused by 1st def.
probably def. is pre-Servilleta
168. Further east tilting during &/and post-Servilleta
Serv. faulted along base of Sangre de Cristo - pre-cutting of Rio Grande Canyon

p.168 - Regional relation of the structure

faults & dip result of movements forming Rio Grande depression

169 Units are more or less symmetric & asymmetric basins.

Española basin is graben-like - near symmetric

Tusas - Tres Piedras region - asymm.

is lower pt. of block depressed along its eastern margin

like Alamosa basin of San Luis Valley,

faults are detail superimposed on large tilted block.

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

170 2 periods of movement on some faults suggests reg. movements spasmodic rather than continuous

Geomorphic aspects of structure

Depression is major geomorph feature because depressed while adjacent areas, esp intr. masses, have been uplifted.

In N pt. of depression uplift on east side effected by normal faulting

On W side, Tusas Mtns & S. pt San Juan Mtns are uplifted E portion of a large tilted block,

Def - broken Rio Grande depression & bordering areas into series of sub-11 strips or blks that trend ≈ N. Sep structural blocks the details of the subsequent physiog develop w/in the blocks has differed.

171 Structure is chief factor which controls physiog. modified by stream erosion,

Rio Vallecito & Tusas Creek located nr lower sides of tilted blocks. Their ~~upper~~ resp. portions prob. consequent on faulting & def. of blks, but the valleys are largely erosional & as they lie in belts of softer beds are subseq.

Tusas Mtns disting. from Taos Plateau largely because of diff. of structure that is expressed by greater relative uplift of the mtns & greater deformation of rx that underlie them.

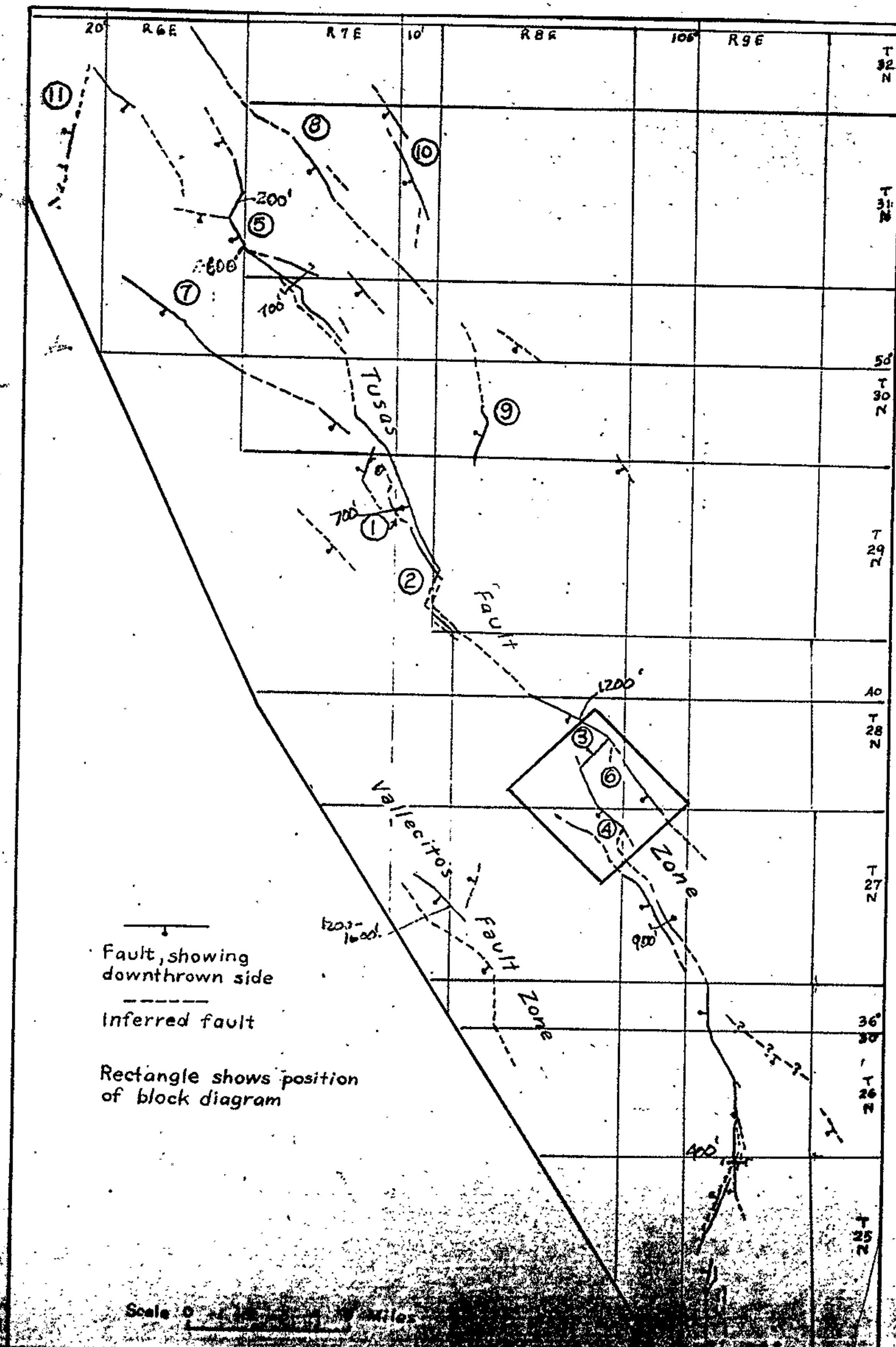

Figure 25 — Map of the ... Tusas - Tres ... New Mexico ... discussed ...

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Summary of the Geomorphology

Introduction

Paramount prob. is SE extension of San Juan peneplain.
prob. post-Los Pinos rather than pre- as believed by Atwood & Mather.

Physiog development post-Dorado complicated by
1. base levels for streams draining N pt area diff. fm streams draining Cent & S pt. of Tusas Mtns
2. faulting w/in mtns has caused details of erosion to be different on the E & W sides of the tilted blks
3. Taos Plateau underlain by ygr rx than mtns & history not same

Position of the San Juan peneplain

name for extensive, mature, sub-summit surface developed during long erosion
173 interval post Fisher latite-andesite. Los Pinos dep on this surface following
uplift of Central San Juan, peneplain completed in late Plio = according Atwood & Mather
Butler corrd Los Pinos w/ Fisher latite-andesite
in N.Mex Los Pinos rests on 1 bed of Treas Mtn for 120 sq. mi.
174 suggests absence of vigorous & widespread erosion
much evidence of long post-Los Pinos erosion prior to Hinsdale bas.
Summit surface 600-800' above Los Pinos R on N.
S. side Rio San Antonio in T30N R7.8E river was stabilized ~300'
175 above present grade
in SW pt. area erosion eliminated 400-500' relief caused by
post-Santa Fe faulting & produced low relief surface on which Dorado extended
176 pЄ on Tres Piedras is benched at level where Los Pinos could be surface cut
& on which Servilleta basalt was erupted.

Mesa de la Jarita upland is post-Los Pinos - does not coincide w/ top of Treas Mtn

Much extensive work needed on geomorph.

177 in vicin of Los Pinos R. remnants of summit surface much too high to correspond
w/ broad valleys developed in eastern pt. of mtns during Florida cycle of
erosion of Atwood & Mather. Only known erosion interval in the San Juan Mtns
w/ which their development might be appropriately correlated is that
during which the San Juan peneplain was developed. Seems likely San Juan
peneplain, or erosion surfaces related [illegible] Los Pinos rather than pre

		Remarks
Hinsdale volcanic series		
Servilleta formation Flow of basalt interbedded with gravel	0-100'+	Previously included in "New Mexico type Hinsdale basalt" and "Hinsdale basalt"
~ Unconformity ~		
Dorado basalt Flows of quartz basalt	0-100'+	Previously included in "Hinsdale basalt"
~ Unconformity ~		
San Antonio "andesite" Hypersthene quartz latite of San Antonio Peak and elsewhere; relative age uncertain	0-2000'	Previously called "andesite domes of the Hinsdale formation."
Cisneros basalt Disconnected bodies of basaltic flows	0-50'	Previously included in "Hinsdale basalt"
~ Unconformity ~		
Santa Fe formation fluviatile and aeolian sandstone	0-1000'	Partly equivalent to, partly younger than Cordito member, occurs only in extreme southeast of area
Los Pinos formation In northern part of the area clastic members are undivided		
Cordito member Rhyolitic sandstone, conglomerate, tuff, flows, and flow breccia	0-700'	Partly equivalent to Santa Fe formation; equivalent in material and time to part of the Abiquiu tuff
~ Local unconformity ~		
Jarita basalt member Disconnected bodies of basaltic flows	0-100'	Previously included in "Hinsdale basalt"; to the south a member of the Abiquiu tuff
Esquibel member Coarsely porphyritic quartz latite, sandstone, tuff, and conglomerate	0-600'	Present only in central part of the area; probably equivalent in time to part of the undivided Los Pinos and part of the Abiquiu tuff
Biscara Member Dark-colored quartz latite; graywacke, conglomerate, breccia, tuff, and flow breccia; some rhyolitic tuff and flow breccia	0-700'	Previously confused with the Conejos andesite. Partly equivalent in time to the undivided Los Pinos, and equivalent in material and time to part of the Abiquiu tuff
~ Unconformity (?) ~		
Treasure Mountain formation Tuff, welded tuff of quartz latite, flows of rhyolite, graywacke, and conglomerate	0-325	Not present in southern part of the area. No identified correlative in the Abiquiu area
Conejos formation Tuff, agglomerate, breccia, flow breccia, and flows of dark-colored quartz and olivine latite; flow breccia and flows of light-colored quartz latite; graywacke and conglomerate	0-1000'+	Not present in southern part of the area. No identified correlative in the Abiquiu area.

Abiquiu tuff

Outline of erosional events in the Tusas Mountains

Event	Drainage Basin: Upper Tusas Valley	Lower Tusas Valley	Rio San Antonio	Los Pinos River
Post-Santa Fe, pre-Hinsdale erosion. San Juan peneplain (?)	Divide east of valley, summits west of divide; upland west of valley	Surface under Hinsdale basalts east of valley; Mesa de la Jarita surface west of valley	Accordant ridges north and south of stream about 300 feet above present grade	Upland of the drainage divide north of stream; 600 to 800 feet above grade
Stabilization 300' above present grade in upper Tusas Valley	Ridge spurs 330 to 400' above present grade	Not represented (?)	Accordant ridges about 300' above present grade (?) Merges eastward w/ pre-Hinsdale surface	Ridge spurs 500' above present grade?
Fill in Tusas Valley and surface cut thereon	Erosion terrace on fill at 70-100' above present grade	?	?	?
200-300' terrace	Possibly same as preceding interval, possibly not represented	Broad valley ~~spurs~~ represented by spurs 200-300' above stream	?	Spurs 300' above stream ?
100-150' terrace	Does not extend above	Ridge spurs 100-150' above stream		

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29 July 1960

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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 "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 Cliffs 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 u 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 to-day. 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.

<u>Southeast Corner</u>.- 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

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 holocrystalline. The basalt capping the little peak is very fine-grained and dense and an olivine basalt. It may be ~~events; on the~~ a vent. 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 glop 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.

<u>General comments on Abiquiu, Santa Fe stratigraphy.</u> - The contact between the Santa Fe and Abiquiu is a little problem in places because lof 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-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, 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 sub-divided.

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 GEOLOGY
OF THE TUSAS-TRES PIEDRAS AREA, NEW MEXICO

by

Arthur P. Butler, Jr.

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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 vulcanism. 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 Servilleta 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 Servilleta 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

p.5 "The principal results of the investigation of the Tertiary geology in the Tusas - 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

p.6 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 Servilleta, 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 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.

p.22 Conejos formation - used instead of C. andesite

23 ~~Distribution~~ Lithology - dark-colored quartz latite breccia characteristic unit. Also includes unbrecciated lava flows, tuff-breccia, agglomerate, and some fluviatile beds, which range from tuffaceous graywacke to poorly sorted conglomerate. Breccia and flows are generally more abundant in the

24 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, tridymite latite and basalt also occur. Tuffs tend to be felsic, and the conglomerates are formed of pebbles and boulders of mixed types, in which dark-colored lavas predominate.

25 gy & gy-gn bec. tend break around the frags, but the mas felsic, purp-gy to red pur brec break across frags.

In composition the flow rocks range from basalt or olivine latite to quartz latite, and the breccias from olivine latite to quartz latite.

darker rx = plag, dk gn pyr, iddingsite after olivine are common pheno. Bio rare.
lighter = plag, bio, att. Hb in variegated brec. rare elsewhere.

26 tuff well-indurated mineral grains & ang peb in fine-grained matrix
grade laterally to tuff-brec or agglom, the matrix of which resembles the tuffs
larger frags ang to rndd cob & peb to 4' diam.
No sorting, no bedding, develop spires & pinnacles.

Thickness - base not exposed at thickest point in Los Pinos Canyon 2 mi. W of east side
R.6E = 1000'. elsewhere will wedge out completely against p€

Origin - chaotic assemblage of clastic & effusive rocks.
massiveness, indistinct bedding, poor sorting of materials, and

27 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 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 mater.

- ordinary flow breccias & breccias in which fragments are set in a tuff-like matrix of different lithology.

mud accidents mechanism

p.28. some probably mudflows
some pyroclastics channeled by streams & backfilled by alluvial deposits

p.29 - Presumed Conejo under Treasure Mountain fm in Tusas Valley correlated
1. volcanic activity suggested by water-laid tuff
2. resemblance between bentonitic arkose & matrix of Conejo agg in Rio San Antonio Valley
3. stratigraphic position
4. presence of considerable non-volcanic material in Conejo in vicinity of Brazos Canyon
5. similarity of between these rx & beds under volc pt. of fm in Summitville quad. Colo.

p.30 <u>Treasure Mountain formation</u> - instead of T.M. quartz latite of Cross & Larsen
Distribution and relation to older rocks.
disconf. on Conejo well exposed E side of small valley N of Los Pinos R in Sec. 33, T32N R7E. relief on top Conejo to 300'.
p31 1 mi S of San Miguel, top bed of T.M. abuts against slope of Conejo.
canyon topog found in Colorado bet. these fm generally lacking.
many places T.M. overlaps Conejo & rests on p€.
Lithology - rhyo & qtz latite lava, welded tuff & tuff breccia, & intergrading tuff, graywacke, and cg
sec. 2, p. 93 - upper ½ flow, lower half tuff
n. side Rio San Antonio upper strata mostly flow.
15 mi. SE - tuff more abun.
flow or flow-like rx confined to base of fm. because of topog sometimes missing.
distinctive bed "welded tuff" marker at top.
flow-like rx at base may be welded tuff - dk gy to blk vit. porphy qtz lat. overlain by flows of similar comp. dull brn to red color,
.32. more abun porph than blk rx & aphan. pheno - plag & bio.
true flows more persistent than blk flow-like rx.
capping welded rhyolite - latite tuff weathers into coarse slabby frags 25' thick
11 to top of bed. commonly lt gy, at many places grades from gy at top through pur-gy to red at bot. lt wt., fine-gn to aph, porph
tab plag, bio, rare prisms gn pyx - pheno
33 - under mic - groundmass - more or less well-preserved bubbles, bubble frags, shards devit. glass fused together some flattened.

p.33. welded tuff ~100' thick in extreme SE corner T32N R7E.
Thins W & S so that along highland W of Beaver Creek & N. Tusas Valley
5-15' thick. Pinches out N of S limit of fm.
Covered 160 sq. mi. in N. Mex. + large area in Colorado.
many places reaches 10' pink to buff, massive but friable, felsitic tuff
good exp 1.2 mi. SE Sublette sec house on D&R.G.
contact undulatory w/ involution of underlying bed into the welded tuff.
34. Bellow welded tuff bulk of section is tuff & tuff-breccia, tuff aces, ss, cg.
intergrade, mid pt. tuff & flow interbedded.
in Beaver Creek a decrepitating bentonitic pink tuff - nr. base of fm.
Cañada Biscara has bed strat. higher similarly altered-
35 finer-grained clastics L-subL, cob & bldrs subL - well rnd & water-worn,
cg bed 1-15'
dk. colored felsite or and predom. among volc rx of cg.
welded-tuff at top only way to distinguish from overlying Los Pinos fm,
in so. pt. unsurveyed T31N R6E & along E side Tusas Valley a consid. pptn
peb & sones beds nearly all derived from pC rx of nearby hills.
Some beds in pC are breccias of hillside rubble
Thickness — 320' on N-side Los Pinos to 60' nr. S. limit of step,
36 Origin - accum. normal airborne tuff, welded tuff, possible flows, and
water-laid volc. tuff & cg. Lacks steep initial dips & abrupt changes in
lith. of Conejos gp, gen. even bedded so that individual beds can be traced wide
center or centers volc. act. farther from N. Mex than prev. Conejos,
lenses of coarse cg in beds fine grnd tuff suggest powerful streams that
were graded for their loads & alter. scoured & filled their channels.
37. welded tuff is lithoidal, mostly massive & unlayered except for locally
vitreous base, rather uniformly fine-grained
in compo. & aspect similar to welded tuff in Idaho; Bishop, Calif, "ignimbrite
of New Zealand.
in comp, text, size similar unwelded tuff of Valley 10,000 smokes, Katmai.

37-40 -- long comparison w/ other tuffs as to origin.
T.M. - well sorted, uniform fine gr. prob. never airborne, never covered higher hills
foreign rock present only locally, some movement of upper tuff over lower.
ave. thickness 25' - 1 cu. mi. rk in N. Mex. maybe distrib. like pumice
flows of Mazama.

p.41 - Significance - most clearly defined strat. unit in N. Tusas Mtns.
allows distinction bet. Conejos & similar Los Pinos fm.

42 - Age of Potosi rx - overlie Burns latite of Silverton volc. series & underlies Creede fm (Cross & Larsen, 1935, pp 51-53). Both Burns & Creede carry Miocene plants (Knowlton, 1922, pp 183-192.

Petrography of Conejos -
rather completely studied by Cross & Larsen 1935
Larsen, Irving, Gonyer, Larsen III (1936-1938)

p.45 - Los Pinos formation

Atwood & Mather - gravel fm on San Juan peneplain & underlying Hinsdale
type locality in vicinity of San Miguel ~600'
scattered deps mainly ss & cg, ~ 1/4 fm tuff & tuff rx.
Cross & Larsen included in Hinsdale.

46 Butler retains main line & uses as fm. Sep. by uncomf from Hinsdale.

Distribution - most widely distrib. unit in map area.
Atwood & Mather - present in vicin of Brazos Canyon.
Some of rx E of El Rito Creek mapped as Abiquiu by Smith prob. Los Pinos
pt. if not all of Abiquiu is equiv. to pt. of Los Pinos fm.

47, distinction bet. 2 fm. diff. to make, Abiquiu may be abandoned

Subdivisions - not uniform laterally or vertically.
S. of Broke Off Mtn. - fm into 4 mem - (1) 3 mem disting from each other by domin. kinds of rk frag consist largely of water-laid graywacke, cg, breccia w/ minor am'ts of tuff & volc. breccia, (2) mem basaltic lava.
N of Broke Off zonation not marked - undivided gravel = "Los Pinos gravel" of Atwood & Mather = 2 lowest mem. to S.; upper basalt.

S. of T.30N & W. of Tusas Creek is shown as undivided - 3 clastic members are present, not enough time to map.

48 - "In the vicinity of the Petaca Mesas the top member of the formation grades laterally from water-laid volcanic gravel and pyroclastic rocks to arkosic sandstone and sandstone that are continuous with the Santa Fe formation of the Abiquiu quadrangle."

Mag. of changes in strat. from E to W across Tusas Mtns appear 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 - predom graywacke, tuffaceous graywacke, fine-grained cg.
more syst. vert. distrib., more tuff near bottom. relat. persist.
cg zone ~100' below top,

generalized strat section in NC T30N R7E n. of Rio San Antonio =

Jarita basalt member	50'
Undivided Los Pinos	
Not exposed, probably fine-grained fluviatile beds	50'
Greenish brown, indurated sandy graywacke & cg cemented by chalcedony; cliff forming	50'
50 Conglomerate and interbedded graywacke or tuffaceous ss; typ. boulder littered slopes	250'
Tuffaceous siltstone, fine-grained & tuffaceous graywacke; may include some tuff	150'
Conglomerate of angular, dark-colored, andesite-like fragments in a matrix of tuffaceous graywacke	100'
Total undivided Los Pinos	600'
Treasure Mountain fm. - not measured	

tuffs are felsic, <r min grns in frag matrix partly devitrified glass,
small <r peb uniformly distrib. thru some beds,
color commonly light gry, but ranges from light buff & cream white.
poorly sorted ss grywke uniform distrib thru entire fm. grades to ss tuff silt
or grywke-cg. lt gry, some lt buff, lt. brn. beds 1/4"-6" few 1'.
51 - x-bedding common. <r grns fel, qtz, bio main constit. of ss-grywke
some pyx, hb, mag gen. present. Presence grns w/ good cl. suggest
short transport - few 10's miles.

cg litters surface - residual rubble. cg beds 1' less, max 10'
lenses & pockets common. sorting rela. good.
thicker beds peb-cob 4"± in diam.
larger bldrs to 4' generally in beds to 2X largest phenoclasts.
in gen, smaller frags subang, less well rnd than larger.
52 along Rio San Antonio, lower cg <r, those 200' above base more rndd.

p.52 - phenoclasts mostly volc rx. mainly intermed- felsites.
Many dk-col and-like peb resemble both rx of underlying Conejos &
of Biscara mem. Partic. abun. in lower pt. present thru all.
fldrs & cob gy-maroon cse porph fel 1.5cm pheno. fel are common,
these peb in channel fillings - unlike any other rx in area or Conejos quad.

53 - NO peb of Treas. Mtn. rx found in Los Pinos fm, even close to contact!

Biscara member — type Cañada Biscara T29N R8E
character by abun of phenoclasts of gen dk-colored qtz latite breccias & cg.
probably correlative w/ pt. of Smith's Abiquiu tuff

55 - can be subdivided into 3 pts distinguished by rel. abun. of
56 dk-col qtz lat, rhyo, pЄ rx in coarser beds
common in lower pt.
lge am't tuff, some brec., some peb in mid pt.
abun, predom. in upper pt. volc brecc. & cg.
close to pЄ hills basal members are unassorted jumble of frags.
57. some arkosic beds
similar to lower Abiquiu tuff
58 - dk col latite - lt gy-gn to mar-gy & blk.
all porph, finely x-line to aph
plag, shiny small hb common pheno.
iddingsite after olivine gives rust-spotting
59 pale gn spots common - prob altered pyx.
bio present in some.
pebbles of these rare strat. above Biscara.
rhyo breccia 70' in SE Dorado Canyon blue-gy aph rk
also small dikes & plugs in this member

61 Esquibel member - characterized by the abundance of peb, cob, bldrs
of conspic porph qtz latite
recog into west pt. R.7E.
62 similar in lith to undiv. Los Pinos N of Broke Off Mtn.
→ gy or pur-pink qtz latite w/ conspic. fel pheno to 8 mm.
bio, hb pheno also pres.
transitional into underlying Esquibel member

p.65 - Esquibel mem laps uncomf around hills of pЄ rk.
believed to be correl of large pt of undivid Los Pinos of N pt. of area.

Jarita basalt member -

66 some of basalt interbedded w/ tuff in Abiquiu quad prob. correlative

67. 1. northern type a. - fine, slightly porph, mod vesic, rusty iddings chal amyg. - more common, on bottom if both present
b. - fine, more porph olio, no inter pore space, irreg vein $CaCO_3$, $CaCO_3$ amyg, pheno pyr

68 2. southern type - basalt, small irreg pale gn or yel-gn spots
superf. alt. of plag. gives moldy look.
sparse pheno of hyp, - inter pore space
dense type w/ rusty idding, plag.
dk gn pyr then ol inconspic.

69 3. central type - fine-grnd, porph, abun. irreg. vesicle.
tab plag 2-5 mm. rusty iddings
some flows w/ sparse qtz & dk gn pyr.

thickness to 100'

70. - Cordito member

71 - predom rhyo, largely flow beds fine-grnd mudstone to cse cg
w/ minor but imp. tuff & lava

72 cg frags = 1. rhyolitic rx - sparse to abun porph. wh, red, pur, blue, gy
qtz, sani, olig
2. porph rx - coarse, feldabun 0.5-1.0 cm. to 2.0 cm.
rhyo or qtz lat.
some bio, hb, qtz. aph matrix

77 Erosional interval preceding the Cordito member is apparently of only local significance.

few small dikes & plugs of pur-pink rhy of this age

No Agua Mountain rhyolite - erodal remnant of rhy vole of Los Pinos

78 thickness of Los Pinos - thickest in N. pt T28N - Biscara 450' + Esq. 650'

79 Cordito 250' to 600'
600-700' Los Pinos R & Broke Off Mtn. - likewise in Brazos R. Max thick 1700'

p-81 - Origin - These descrip. do not fit concept of Atwood & Mather who believed was pt. of alluvial apron from renewed uplift of San Juan Mtns.
There is no tangible evidence that alluvial beds are result of older volcanic terrane.

Charact. pertinent to origin: 1. lava flows, breccias & tuffs interb w/ alluvial dep
2. many of types of rx in gravel petrog. similar to interbed eruptives
3. kind of pebbles changes systematically from one member to another
4. many of the larger frags in cg differ from pre-Los Pinos volc rx of
82 San Juan Mtns. that crop out w/in a distance from which such large frags could be transported
5. changes in lith of fm more marked from N to S than W to E.
1&2 indicate much of material from active volc. centers
3 is change in eruptive character of rx or change in locus of eruption
undivided pt. from multiple sources.
4 Conejos buried by Tusas Mtns for at least 20 mi to NW. ∴ dk-color latite from other source.
83 biggest boulders in Rio San Antonio not Los Pinos R. 5-9' diam.
84 5 undiff Los Pinos, stream sources different from those dep - Bis, Esq. Cordits
change in lith must be result streams travelling 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 Tusas quad 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 NE source of Los Pinos =
1. all data points to east source for Santa Fe
2. Jarita basalt from vents in E pt. or E of mapped area
∴ surface sloped W or SW.
all known vents of younger basalts, etc in Brazos Canyon are on E of Tusas Mtns
Taos plateau has obviously been an area of eruption during a long period.
∠arity of frags + prox of pЄ frags to steps indicate local origin.
87. many places volc rx against pЄ w/o intervening debris.
fresh arkose + absence colored clayey matrix in beds from pЄ suggests relatively dry climate.

p.92 · Stratigraphic Sections

Section 1, Conejos formation on north side of the Los Pinos River in NW¼ sec 31, T32N R7E

Conejo formation

Quartz latite breccia, gray-green, probably near rhyolite in composition 100+

Qtz lat massive & brec. flows, p[illegible]-pink to pur-gy, pheno of plag, bio, sparse clinopyx in aph groundmass, frag & matrix closely similar 210

Qtz lat, gy-gn & gy, nr andesite in comp, interbedded aggl & br 55

Qtz lat, nr. and in comp, in pt. olivine latite, dk greenish gy porph rk, some plag & rusty iddings after olio, interbed agg, br & flow 40

Qtz latite, mostly gy & gy-grn br alternating & interbedded w/ olive drab flow & breccia prob. olio lat, locally rk bleached white by alteration, which includes silicification 60+

agglomerate w/ lge rounded frags in tuff matrix, interbd tuff & tuff ss, mostly gy to gy-grn, fills channels in underlying rk 10-65

93 Local unconformity ——

Qtz lat pyro br, pastel gy-gn to pale maroon frags in lt. maroon gy matrix, pheno shiny blk hb, plag, [illegible] 105-50

Brec & agg of lge random frags in tuff matrix, gy-tuff & gnsh gy 35

Tuffaceous SS or graywacke, gray 5

Not exposed to level of Los Pinos River 55

Total thickness measured 675+

Vertical range of exposure 765, dips are irregular in direction and amount

p. 93. Section 2. Treasure Mountain formation on north side of Los Pinos River, sec. 33, T. 32 N., R. 7 E.

Treasure Mountain formation, top

Welded tuff of quartz latite, gray to pink, massive	58
Tuff, pink, friable – general resemblance to overlying welded tuff	5
Graywacke cg, lge cob cg, & gywcke, interb; bds lge cob cg 8' thick	61
Tuff, buff, felsic overlies fine-grained gy felsic tuff	16
Sandstone, buff, fine-grained, tuffaceous	9
94 Cobble cg, well-cemented overlies gy sandy cg	29
Tuff & tuff-br, felsic, gy to buff, interb, carries 5' bed of cg in mid	50
Poorly exposed, mostly gy tuff & tuff-breccia, some interb water-laid gywcke & cg	50
Rhyolitic tuff or tuff-br, massive, elsewhere but not in this section closely assoc. w/ brn, olive-brn or red-brn flows of rhyo	15
Total Treasure Mountain	275

Conejos formation

Olivine latite, gy, gn flecked, massive somewhat porph, pheno of dk gn pyx, plag, oliv & iddingsite after oliv — not measured p.44 · Section 5, Treasure Mountain formation near southern limit of exposure, sec. 15, T.28N., R.8E.

	Top not exposed, indefinite, probably consists of cg of ∠ & sub∠ frag of p€	not measured
	Tuff, felsic, pk, friable, carried chalky frags of pumice & bio flakes	10
	Ss, tuff arkosic, & ss cg of frags of p€ rk	20
	Tuff, fragmental, ind, gy-brn, chalky frag of pumice, grains of fel & bio	20
95	Rhyolite flow, olive brn, slightly porph, pheno fel & bio in aph grndmss	20
	No exposure, prob cg of frags of p€	not measured
	Total measured thickness	70

p.95 Section 4. Undivided Los Pinos formation on the east side of the Rio San Antonio, sec. 5, T.30N., R.7E.

Erosion surface	
Jarita basalt member, 3 flows or flow units	40
Undivided gravel member	
Sedimentary beds, not exposed	125
SS & cg, interb, well-ind, cem by chalc-SiO_2, some ss-argillite at bot	50
Graywke, tuffa, lt brn to gy, well-bdd, partly ind; tuffa-ss, & grav-tuff	110
Cg & ss-cg of mixed frags dk-colored qtz lat & cosly porph qtz lat frag	10
Tuff, water-laid, massive & thin-bdd, inter-bdd thin lenses tuffa cg-grywke	65
Cg, tuffa, small-peb, & tuffa grywke	60
96 Tuff, peb, mass, poor bdd, bds qtz lat cg bldrs to 2' diam	15
Cg, lge cob, mostly dk col qtz lat, poorly sorted peb cg & tuffa grywke in upper pt	32
Cg, sm. peb, ∠ dk-col. qtz lat, grades up to tuffa grywke, scattered lnss, peb, bldrs, some thin bds cg, ∠ small peb	30
Tuff, some lenses of cg of conspic. porph frags of qtz lat	15
Silt, tuffa, well-bdd, & fine-grnd tuffa grywke	20
Rhyolite tuff-breccia, prom. frag of pumice	12
Tuff or tuffa grywke, well-bdd, gy, some thin beds w/ pumice frag	13
Total thickness measured	597

p. 96 - Section 5. Composite section of the lower part of the Cordito member, the Jarita basalt member, and part of the Biscara member of the Los Pinos formation on the east side of Tusas Creek, sec. 19, 29, T. 27 N., R. 9 E.

Cordito member

Covered slope, top not exposed	not measured
Sandstone, friable, partly tuffaceous, buff, poorly exposed	55
97 SS, well-ind, muddy, lt brn, w/ local lenses of cg in upper 1/3, mostly frags rhyo, some qtz lat & basalt	33
Poorly exposed, prob. friable lt brn ss w/ local lenses of cg	22
Cg lenses, sub < 1 frags rhyo in matrix of muddy sand, local beds of muddy ss	10
Cg, tuffa, gy of < 1 peb of rhyo & some scoria bas	9
Not exposed	9
Tuff, mottled white, pk, & brn, grading to underlying beds, poorly exp	18
Ss, arkosic, cream gy, tuffa at top w/ white frags decomp glass ~~at top,~~ in upper pt, arkosic w/ conspic flakes of musc slightly cg in lower pt, poorly exp toward top & bot	37
Total Cordito member measured	193

Jarita basalt member

One - 2 basaltic flows, some cg	14 - 49

Biscara member

Cg of frags pC rx prob. top Esquibel mem but mapped as Biscara	18
Local unconformity	
Cg, tuffa, frags dk col qtz lat, some frag csly porph rk, poorly exp	37
Tuff & peb tuff, pinkish-wh, rhyo, mixed w/ gravelly qtz lat tuff & tuff br; dips steep & irregular	87
Base not exposed	
Total Biscara & Jarita members	158
Total thickness measured	351

p.149
150

Table 3 – Treasure Mountain welded tuff from NE corner unsurveyed T.30N., R.6E., 1 mi S. of big bend on Rio San Antonio, 7 miles west of San Antone ranger station; analysis by J.G. Fairchild

Analysis		Norm		Modes	
SiO_2	75.79	Q	41.94	Qtz	—
Al_2O_3	11.63	or	20.57	Orth	trace
Fe_2O_3	1.99	ab	23.58	Plag	20 (An_{30})
FeO	0.25	an	8.34	Aug	trace
MgO	0.49	C	.20	Olio	—
CaO	1.70	di	—	Bio	2
Na_2O	2.76	hy	1.20	Mag	—
K_2O	3.47	ol	—	Groundmass	77
H_2O^-	0.46	mt	—		
H_2O^+	0.73	il	.61		
TiO_2	0.35	hm	.61		
P_2O_5	trace	ap	—		
MnO	0.04				
Sum	99.66				

(from E.S. Larsen, unpub manuscript)

(from Wells, 1937, p.35, Col.3B)

p.151

STRUCTURE

General statement

area in transition zone. N & NW dome arched up & dissected = San Juan Mtns
E & S depression of structural trough w/ ext Pleist erosion =
relat. low plateaus & valleys of Rio Grande Depression
In this area, rx also deformed & main geomorphic features are expression of the larger structural elements somewhat modified by erosion
pC structure not studied. However, structure of Tert rx represent lesser features superimposed on a larger block that is composed of pre-Tert, chiefly pC rx. W. pt. of Tusas Mtns marks line of culmination of a major uplift of which structure has not been completely worked out.
152 This tilted block ends along W. ft Sangre de Cristo where pre-Tert rx abruptly uplifted, prob. by normal faulting,
w/in Tusas-Tres Piedras area the def. of Tert rx consists of general eastward tilting & mod. displacement on a group of related normal faults

Structure of the area proper

Tilting = dip 4-6° east. locally near faults to 25-30°
reversals nr. dips usually WSW in direction of downthrow
Conejos has local dips < 6° - initial dips of coe-gnd pyro rx
153 basalts younger than Los Pinos rarely < 3°
Tres Piedras north gen strike N15-30°W
South more northerly
154 Original dip of Los Pinos from NW to SE. Today other direction

Faults = partial en echelon arrangement into 2 fault zones - Tusas & Vallecitos fault zone.
2 sets but part of 1 system.
"main faults" - longer, trend w/ general strike of the fault-zones
155 "cross faults" - shorter, transfer displacement from one main fault to another & are an integral part of system
Criteria of faulting - rarely exp, abrupt repetition of strata & displacement of distinctive beds, Petaca Mesas - eroded fault scarp
silicification in Santa Fe beds - dip 65°W.
Elsewhere only planes of minor faults ~⊥ to main faults measured dip 70-80° NW or SE.

p.155 Tusas fault zone - 44 mi in area & extends S
156 Single fault or 2-3 sub ll faults.
max. width zone 3 mi.
Petaca Mesas N - N25-30W trend to zone
1 mi. S. Sevilleta Plaza 67°W dip
m. mid sec 24, T28N R8E, 77° WNW dip on small fault
157 Almost w/o exception the west side of main faults is downthrown
small graben 1.25 mi. N of Sevilleta Plaza.
main faults not persistent along strike - die out or abruptly offset by X-faults
Petaca Mesas - 10 mi. long.
Some branch into 2 faults that continue for miles;
others branch & die out.
block diag fig. 27 shows en ech w/ X faults
strike faults
158 because relat. steep dip, strike faults, strat. throw ≈ dip slips.
displacements noted marked on fig. 27
159 X. fault gen N 40-65°E
2 types X-faults recog: 1 = those that offset or transfer displacement on main faults from 1 to another
2. those which do not appear to affect the position of the main faults.
only a few of these have been map.
2, 3, 4 on fig 27 important X-faults. cause drainage changes
N side down
5, 6 - type 2 X-faults. either side down
160 type 1 do not cross main faults
fracturing rather than bending of strata
Valleatos fault zone = only partially mapped
at least 2 main faults & related X-faults N 40 W trend in map area
E of N in Abiquiu quad
161 incomplete data, combined displacement 1600' max, 1200' min.
Other faults = 8, 9, 10, 11 lie outside Tusas fault zone & independent
7 branches NW from Tusas fault zone 1 mi W Broke Off Mtn,
~~strike~~ no. 10 passes into 2 en echelon monoclines at S. end.
show well on Santa fe's on inclined mesa bet. Rio San Antonio &
Los Pinos R.
strike N20-45W. similar to Tusas fault zone exc displacement less than 200'

p.162 - Two periods of movement on faults = all known faults are younger than Los Pinos fm. prob. younger than Santa Fe & pre-Dorado basalt.
2nd movement after Dorado & possibly after Servilleta basalt also.
Post-Servilleta faulting is inferred only from topo exp. at one place east of Comanche Canyon in T.26N., R.10E. & on general evidence of def. of fm.

163 2nd movement not present on some of faults.
½ mi E. D&RG pumping sta in Los Pinos R. canyon offsets Santa, Servilleta undist

164 Petaca Mesas. show 2 deform. well.
fault 9 - 2 displ. 40' pre-Cisneros 20' post

165 renewal of faulting general rather than local cause.
pre-Serv faulting caused locus & condit. of Servilleta to be distinctly diff from those that prevailed during the deposition of the Los Pinos & older

Age of deformation =
pЄ & post Los Pinos only deformations w/ visible record in this area.
deformed Cret rx to W., in Colo, Sangre de Cristo = Laramide?
early Tert - renewed tect. movements → basins for terrest depos.

pre-volcanic Tert, { Blanco Basin on beveled Cret
Vallejo fm. - Eo or Oligo in NE Rio Grande Dep (upson)
El Rito fm Eocene(?)
166 Picuris tuff

probably uplift & erosion to pЄ in this area
no evidence of def. between Potosi & Los Pinos as inferred by Atwood & Mather
San Juan peneplain probably post- Los Pinos.
accum. of basin deposits (Santa Fe, Los Pinos) implies some deformation

167 - 1st episode Tert def. recorded post - Santa Fe or late Pliocene
interval of erosion, extrusion of Cisneros & Dorado bas.
2nd episode post these ↗ exact age not known.
suff. time to reduce 500' relief caused by 1st def.
probably def. is pre-Servilleta

168. Further east tilting during or/and post- Servilleta
Serv. faulted along base of Sangre de Cristo - pre cutting of Rio Grande Canyon.

p.168 — Regional relation of the structure

faults & dip result of movements forming Rio Grande depression

169 Units are more or less symmetric & asymmetric basins.

Española basin is graben-like — near symmetric

Tusas-Tres Piedras region - asymm.

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

faults are detail superimposed on large tilted block.

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

170 2 periods of movement on some faults suggests reg. movements spasmodic rather than continuous

Geomorphic aspects of structure

Depression is major geomorph feature because depressed while adjacent areas, esp intr. masses, have been uplifted.

In N pt. of depression uplift on east side effected by normal faulting

On W side, Tusas Mtns & S. pt San Juan Mtns are uplifted ~~E~~ portion of a large tilted block.

Def. broken Rio Grande depression & bordering areas into series of sub-‖ strips or blks that trend ≈ N. Sep structural blocks the details of the subsequent physiog develop w/in the blocks has differed.

171 Structure is chief factor which controls physiog. modified by stream erosion.

Rio Vallecito & Tusas Creek located nr lower side of tilted blocks. Their ~~upstate~~ resp portions prob. consequent on faulting & def. of blks, but the valleys are largely erosional & as they lie in belts of softer beds are subsequent

Tusas Mtns disting. from Taos Plateau largely because of diff. of structure that is expressed by greater relative uplift of the mtns & greater deformation of rx that underlie them.

P.172

Summary of the Geomorphology

Introduction

Paramount prob. is SE extension of San Juan peneplain,
prob. post-Los Pinos rather than pre- as believed by Atwood & Mather.

Physiog development post-Dorado complicated by
1. base levels for streams draining N pt area diff. fm streams draining Cent & S pt. of Tusas Mtns
2. faulting w/in mtns has caused details of erosion to be different on the E & W sides of the tilted blks
3. Taos Plateau underlain by ygr rx than mtns & history not same

Position of the San Juan peneplain

name for extensive, mature, sub-summit surface developed during long erosion
173 interval post Fisher latite-andesite. Los Pinos dep on this surface following
uplift of Central San Juan, peneplain completed in late Plio - according Atwood & Mather
Butler corsel Los Pinos w/ Fisher latite-andesite
in N.Mex Los Pinos rests on 1 bed of Treas Mtns for 120 sq. mi.
174 suggests absence of vigorous & widespread erosion
much evidence of long post-Los Pinos erosion prior to Hinsdale bas.
Summit surface 600-800' above Los Pinos R on N,
S. side Rio San Antonio in T30N R7.8E river was stabilized ~300'
175 above present grade
in SW pt. area erosion eliminated 400-500' relief caused by
post-Santa Fe faulting & produced low relief surface on which Dorado extruded
176 pЄ on Tres Piedras is benched at level where Los Pinos could be surface cut & on which Servilleta basalt was erupted.

Mesa de la Santa upland is post-Los Pinos - does not coincide w/ top of Treas Mtns
Much extensive work needed on geomorph.

177 in vicin of Los Pinos R. remnants of summit surface much too high to correspond w/ broad valleys developed in eastern pt. of mtns during Florida cycle of erosion of Atwood & Mather. Only known erosion interval in the San Juan Mtns w/ which their development might be appropriately correlated is that during which the San Juan peneplain was developed. Seems likely, ∴, San Juan peneplain, or erosion surfaces related thereto, are post-Los Pinos rather than pre-.

Table 1. – Stratigraphic column of the Tertiary rocks of the Tusas–Tres Piedras area, New Mexico

			Remarks
Hinsdale volcanic series	Servilleta formation Flow of basalt interbedded with gravel	0-100'+	Previously included in "New Mexico type Hinsdale basalt" and "Hinsdale basalt"
	~~ Unconformity ~~		
	Dorado basalt Flows of quartz basalt	0-100'+	Previously included in "Hinsdale basalt"
	~~ Unconformity ~~		
	San Antonio "andesite" Hypersthene quartz latite of San Antonio Peak and elsewhere; relative age uncertain	0-2000'	Previously called "andesite domes of the Hinsdale formation."
	Cisneros basalt Disconnected bodies of basaltic flows	0-50'	Previously included in "Hinsdale basalt"
	~~ Unconformity ~~		
	Santa Fe formation fluviatile and aeolian sandstone	0-1000'	Partly equivalent to, partly younger than Cordito member; occurs only in extreme southeast of area
Los Pinos formation In northern part of the area clastic members are undivided	Cordito member Rhyolitic sandstone, conglomerate, tuff, flows, and flow breccia	0-700'	Partly equivalent to Santa Fe formation; equivalent in material and time to part of the Abiquiu tuff
	~~ Local unconformity ~~		
	Jarita basalt member Disconnected bodies of basaltic flows	0-100'	Previously included in 'Hinsdale basalt'; to the south a member of the Abiquiu tuff
	Esquibel member Coarsely porphyritic quartz latite, sandstone, tuff, and conglomerate	0-600'	Present only in central part of the area; probably equivalent in time to part of the undivided Los Pinos and part of the Abiquiu tuff
	Biscara Member Dark-colored quartz latite; graywacke, conglomerate, breccia, tuff, and flow breccia; some rhyolitic tuff and flow breccia	0-700'	Previously confused with the Conejos andesite. Partly equivalent in time to the undivided Los Pinos, and equivalent in material and time to part of the Abiquiu tuff
	~~ Unconformity(?) ~~		
	Treasure Mountain formation Tuff, welded tuff of quartz latite, flows of rhyolite, graywacke, and conglomerate	0-325	Not present in southern part of the area. No identified correlative in the Abiquiu area
	Conejos formation Tuff, agglomerate, breccia, flow breccia, and flows of dark-colored quartz and olivine latite; flow breccia and flows of light-colored quartz latite; graywacke and conglomerate	0-1000'+	Not present in southern part of the area. No identified correlatives in the Abiquiu area.

(Right margin, bracketing Cordito through Biscara members: Abiquiu tuff)

Table 4
Outline of erosional events in the Tusas Mountains

Event	Drainage Basin: Upper Tusas Valley	Lower Tusas Valley	Rio San Antonio	Los Pinos River
Post-Santa Fe, pre-Hinsdale erosion. San Juan peneplain (?)	Divide east of valley, summits west of divide; upland west of valley	Surface under Hinsdale basalts east of valley; Mesa de la Jarita surface west of valley	Accordant ridges north and south of stream about 300 feet above present grade	Upland of the drainage divide north of stream; 600 to 800 feet above grade
Stabilization 300' above present grade in upper Tusas Valley	Ridge spurs 330 to 400' above present grade	Not represented (?)	Accordant ridges about 300' above present grade (?) Merges eastward w/ pre-Hinsdale surface	Ridge spurs 500' above present grade?
Fill in Tusas Valley and surface cut thereon	Erosion terrace on fill at 70-100' above present grade	?	?	?
200-300' terrace	Possibly same as preceding interval, possibly not represented	Broad valley ~~spurs~~ represented by spurs 200-300' above stream	?	Spurs 300' above stream ?
100-150' terrace	Does not extend above	Ridge spurs 100-150' above stream		

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29 July 1960

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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 "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 Cliffs 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 u 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 to-day. 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 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 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. a vent

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 glop 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.

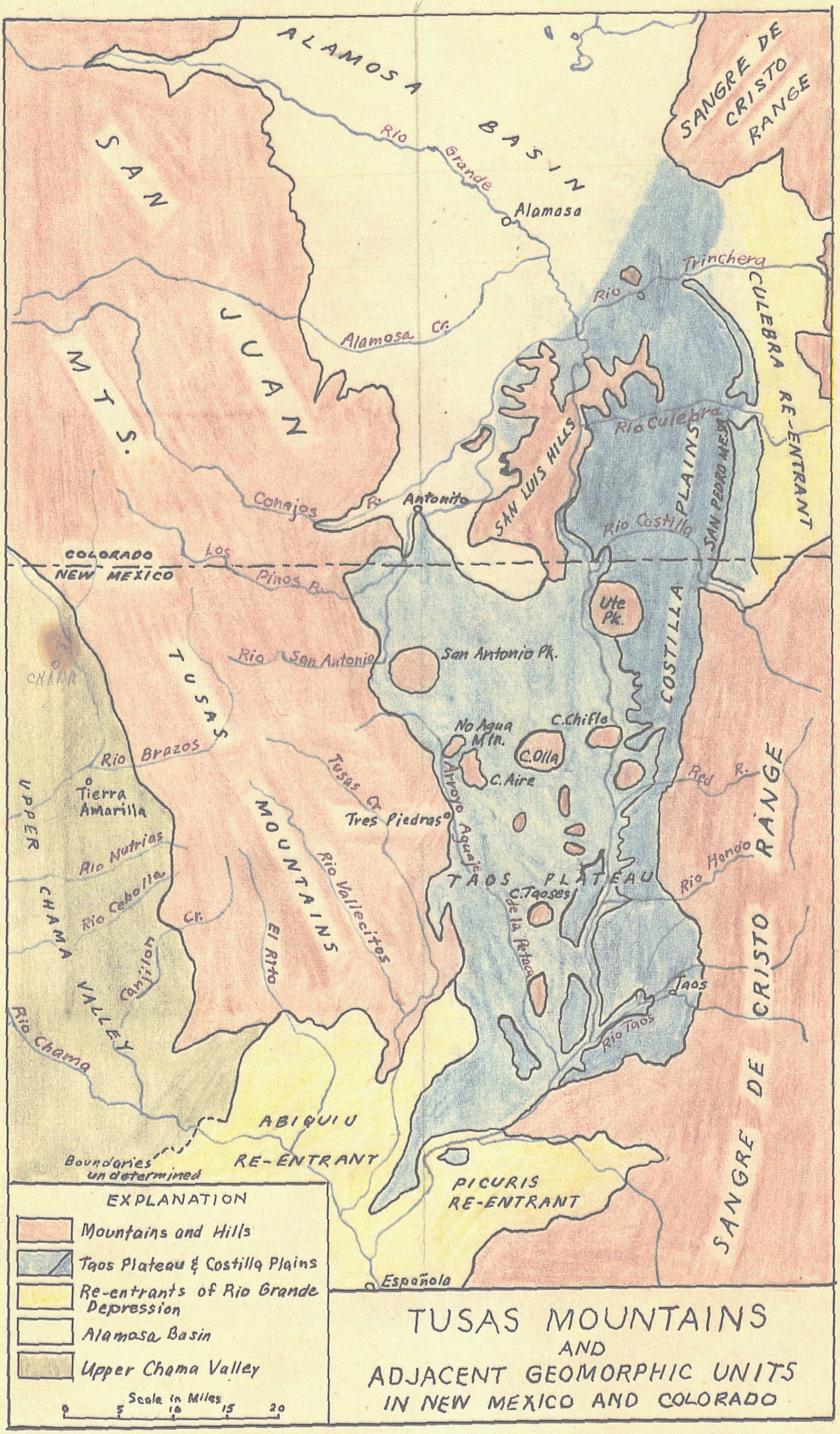
General comments on Abiquiu, Santa Fe stratigraphy. - The contact between the Santa Fe and Abiquiu is a little problem in places because of the inter-bedding of the two types of lithology. In particular, northeast of Ojo Caliente where I first started, you will find a unit marked "TAS" Abiquiu-Santa 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-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, 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.

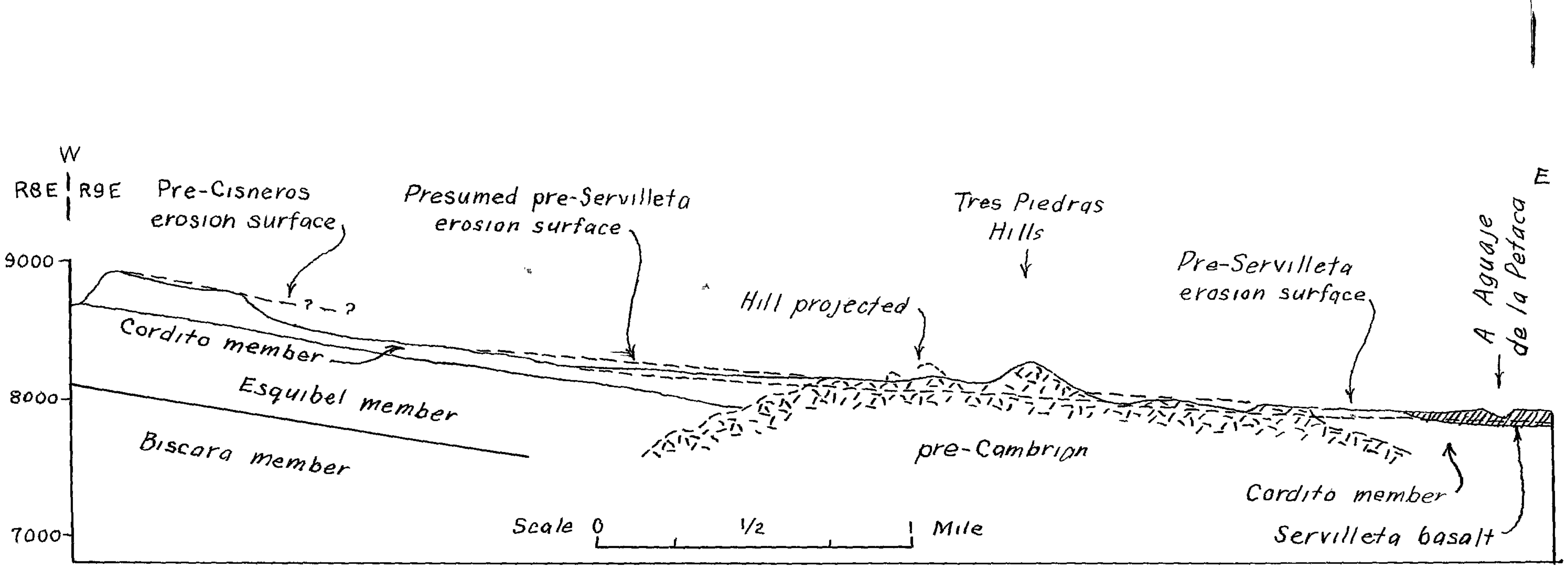
Miscellaneous Items. - How about the possibility that the oldest high terraces are equivalent of the Ancha formation of Baldwin?

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.

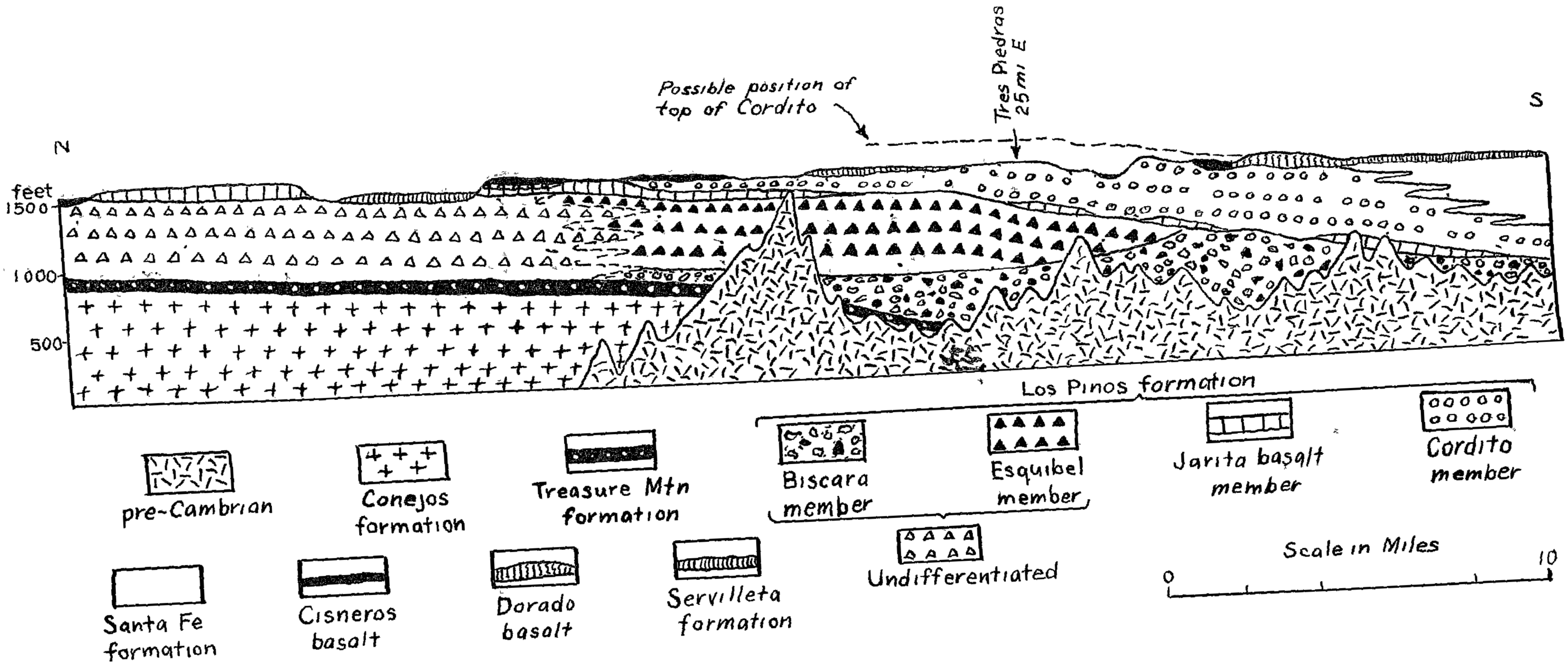


TUSAS MOUNTAINS AND ADJACENT GEOMORPHIC UNITS IN NEW MEXICO AND COLORADO



W
E
R8E
R9E
Pre-Cisneros erosion surface
Presumed pre-Servilleta erosion surface
Tres Piedras Hills
Pre-Servilleta erosion surface
A Aguaje de la Petaca
Hill projected
9000
8000
7000
Cordito member
Esquibel member
Biscara member
pre-Cambrian
Cordito member
Servilleta basalt
Scale 0 1/2 1 Mile

Figure 8 – Generalized section in the eastern part of the Tusas-Tres Piedras area to show the stratigraphic relat[illegible] eliminated and present surface is assumed to be essentially horizontal. Relief is diagrammatic



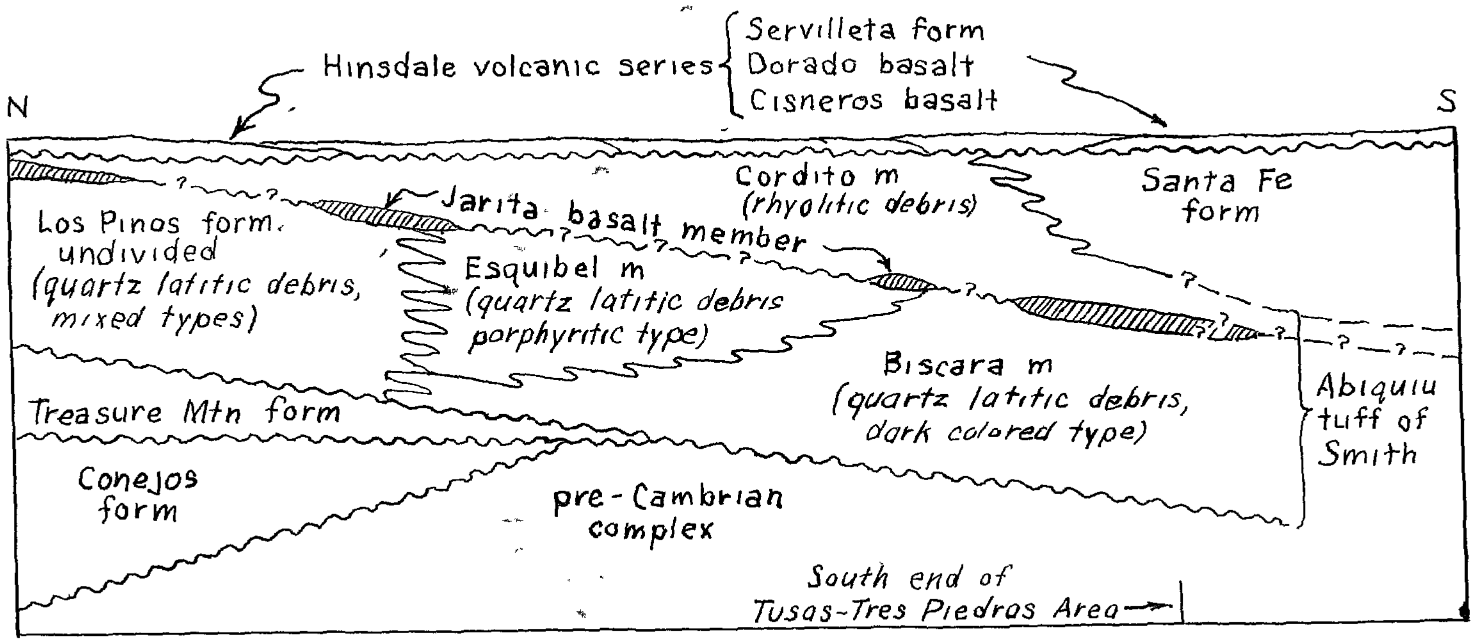
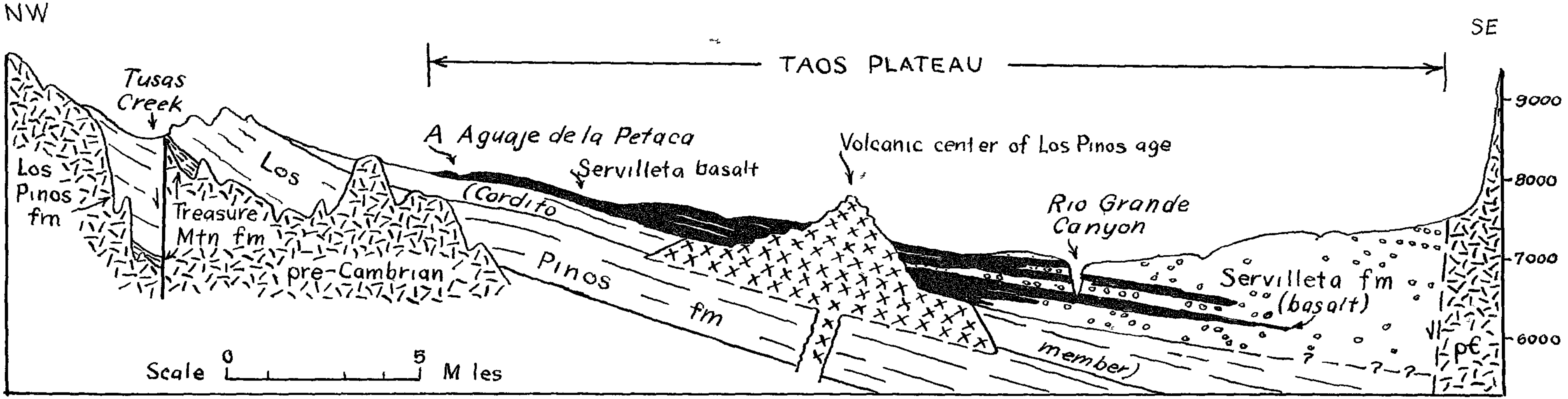


Figure 9 - Diagrammatic correlation chart of the Tertiary rocks of the Tusas-Tres Piedras area, New Mexico Relationships between the Hinsdale formations are not shown Chart is not to scale,

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 interfingering of basalt and gravel and the asymmetry of the basin of accumulation.



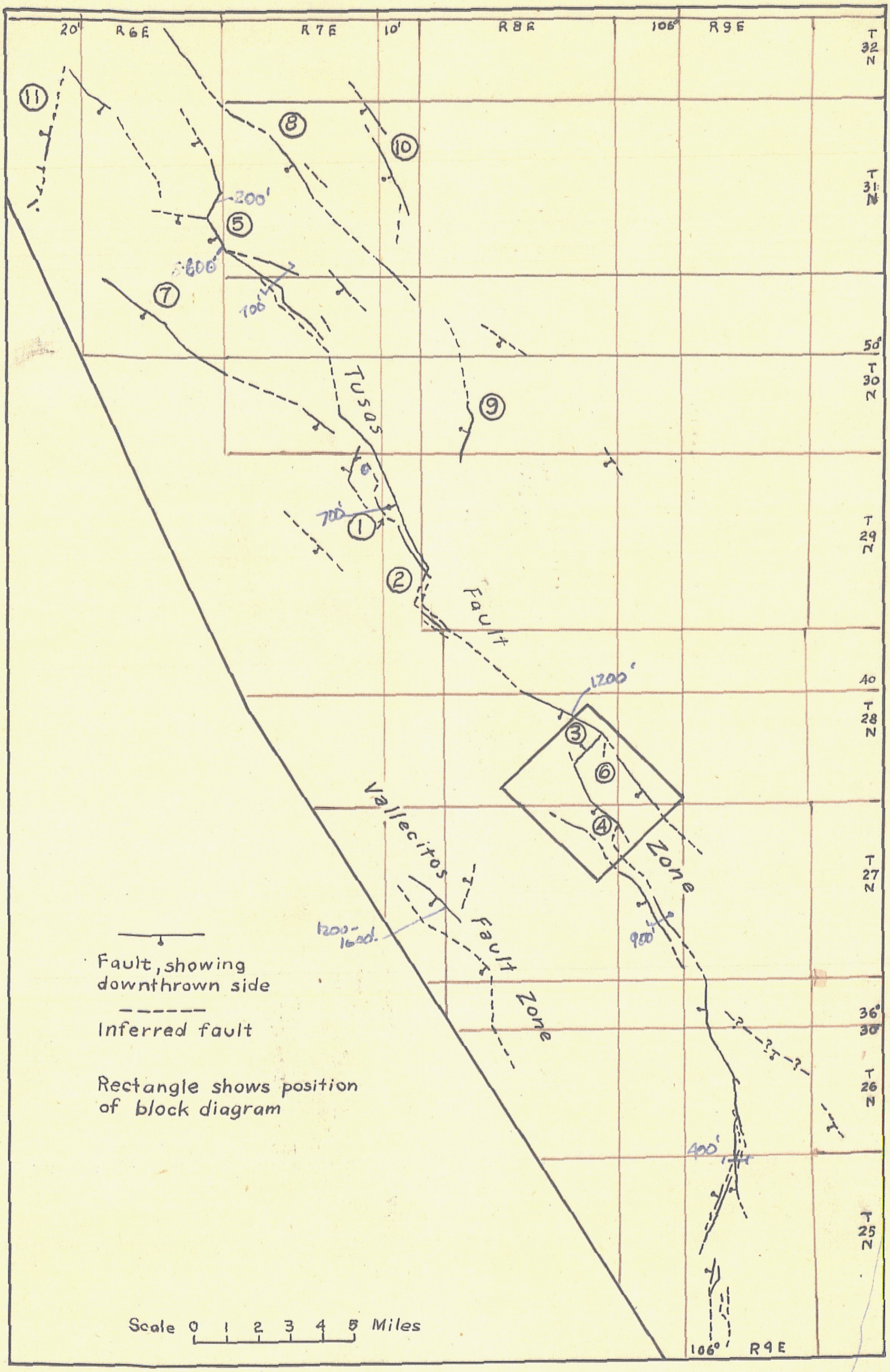
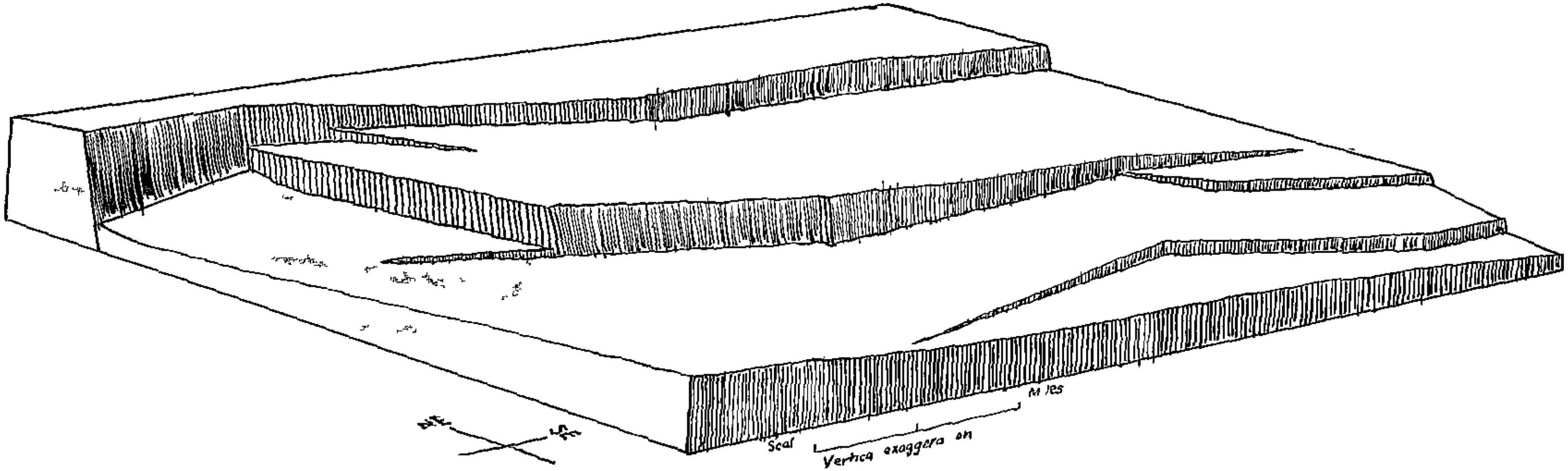


Figure 25 - Map of the principal faults of the Tusas - Tres Piedras area, New Mexico. Numbers refer to localities discussed in the text.



Fgure 27— Block diagram of the Tusas fault zone in Ts. 27 and 28 N., Rs 8 and 9 E. The top surface of the diagram represents the base of the Cordito member of the Los Pinos formation. Position of the diagram is indicated by box on the fault map, figure 25

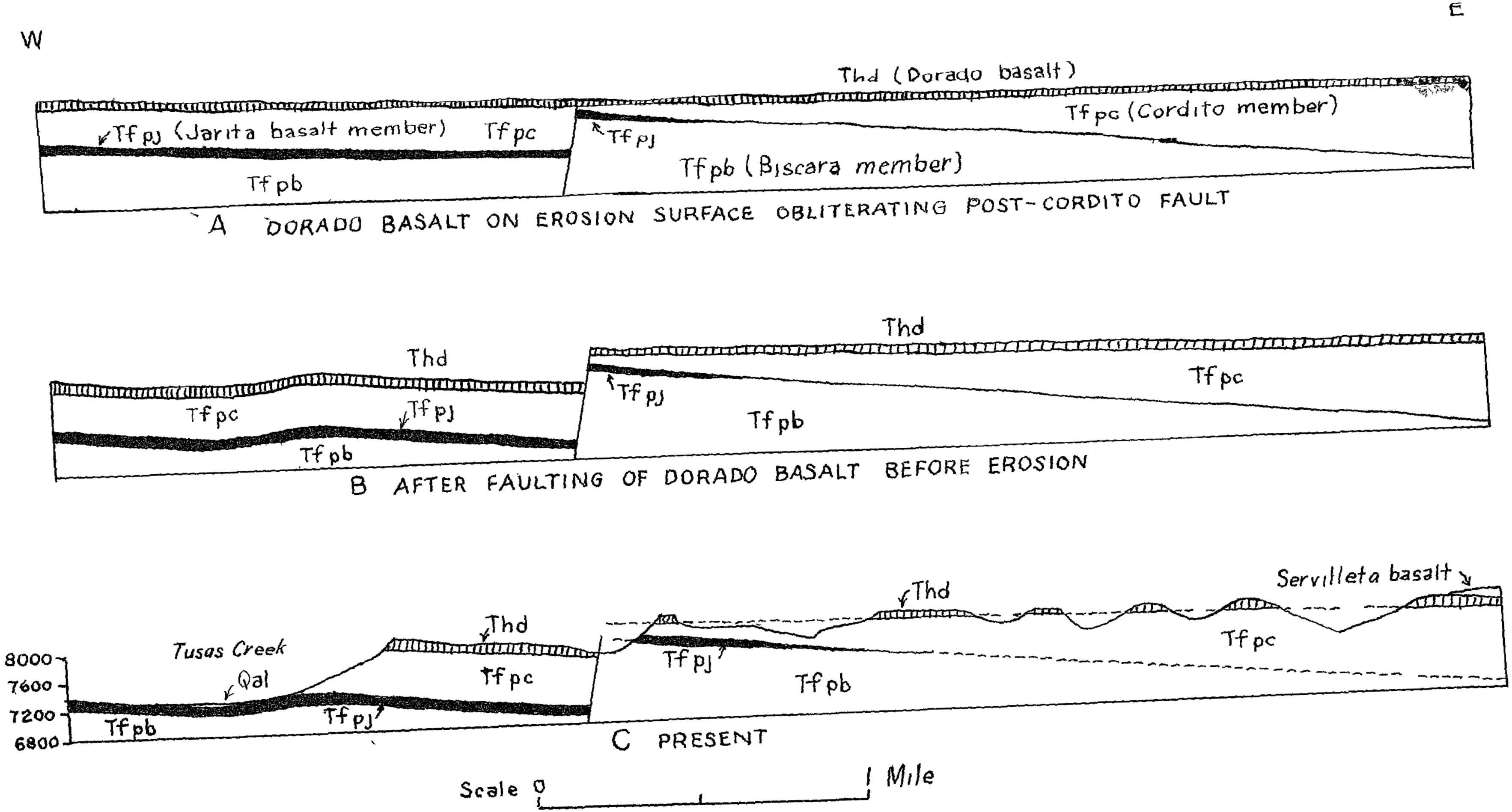


Figure 29 - Section in the southern part of T 27N, R 9E, and across the north end of the Petaca Mesas illustrating two periods of movement on the same fault. This fault constitutes the Tusas fault zone at this point.

Tusas Mtn.
Kiawa Mtn.
Tres Piedras
Canyon de Cordito
Las Tablas
Mesa de la Jarita
Vallecitos
Rio Vallecitos
Petaca
Mesas Petaca
Servilleta
Servilleta Plaza
Comanche Canyon
Tusas Creek
Rio Arriba Co.
Taos Co.
State Highway 74
Denver and Rio Grande Western (Abandoned)
Pliocene
Miocene
Magnetic North
Mean Magnetic Declination 1936
Contact
Contact approximate
Fault showing downthrown side and dip.
Inferred fault
Fault buried by younger rocks
Strike and dip of stratified rocks
Base map compiled by New Mexico State Highway Commission from various sources
Geology by A. P. Butler, Jr., assisted by D. C. Cox, H. E. Wright, J. H. Eric, C. E. Stearns, D. Jackson
1937-38-39

GEOLOGIC MAP OF THE TUSAS-TRES PIEDRAS AREA NEW MEXICO

EXPLANATION

QUATERNARY

Qal / Qls / Qsg

(Alluvium, Qal; landslides, Qls; shown only where deposits obscure older rocks; sand, partly aeolian, and gravel, Qsg.)

EROSION SURFACE

TERTIARY

HINSDALE VOLCANIC SERIES — PLIOCENE

Ths

Servilleta formation

(basalt and interbedded gravel of the Taos Plateau)

EROSION SURFACE

Thd

Dorado basalt

(quartz-basalt; local flows)

Tha

San Antonio Andesite

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

EROSION SURFACE

Thc

Cisneros basalt

(widely distributed, disconnected flows)

EROSION SURFACE

FISHER (?)

Tfpc / Tfci

Cordito member

(tuffaceous sandstone, conglomerate of rhyolite fragments, rhyolite flows and breccia; intrusives; rhyolite pipes, Tfci.)

Tsf

Santa Fe formation

(fluviatile and aeolian sandstone and subordinate conglomerate; grades laterally into Cordito member.)

EROSION SURFACE

Tfpj

Jarita basalt member

(basalt and hypersthene basalt)

Tfpe

Esquibel member

(tuffaceous sandstone, tuff and conglomerate of coarsely porphyritic latite-andesite fragments)

Tfpb / Tfbi

Biscara member

(tuffaceous sandstone interbedded with conglomerate and breccia of andesite and andesite-latite fragments; rhyolite tuff and breccia; dikes and pipes of intrusive andesite-latite and rhyolite, Tfbi.)

Tfp / Tfpb

Los Pinos formation

(stream-laid sandstone and conglomerate of volcanic fragments, and tuff; undivided Los Pinos, Tfp, is mostly equivalent to Esquibel and Biscara members; contains local basalt flows, Tfpb.)

EROSION SURFACE (?)

POTOSI VOLCANIC SERIES — MIOCENE

Tptr / Tpt

Treasure Mountain formation

(rhyolite and quartz-latite tuff, sandstone and conglomerate of volcanic fragments, and rhyolite flows, Tpt; at top welded rhyolite tuff, Tptr.)

Tpc

Conejos formation

(andesite and andesite-latite breccia and flows interbedded with tuff; subordinate sandstone and conglomerate)

EROSION SURFACE

(Result of profound erosion during one or more long intervals)

PRE-CAMBRIAN

pЄ

Pre-Cambrian rocks

(Undifferentiated igneous and metamorphic rocks)

Mean Mag

C

C

F

I

F

12 S

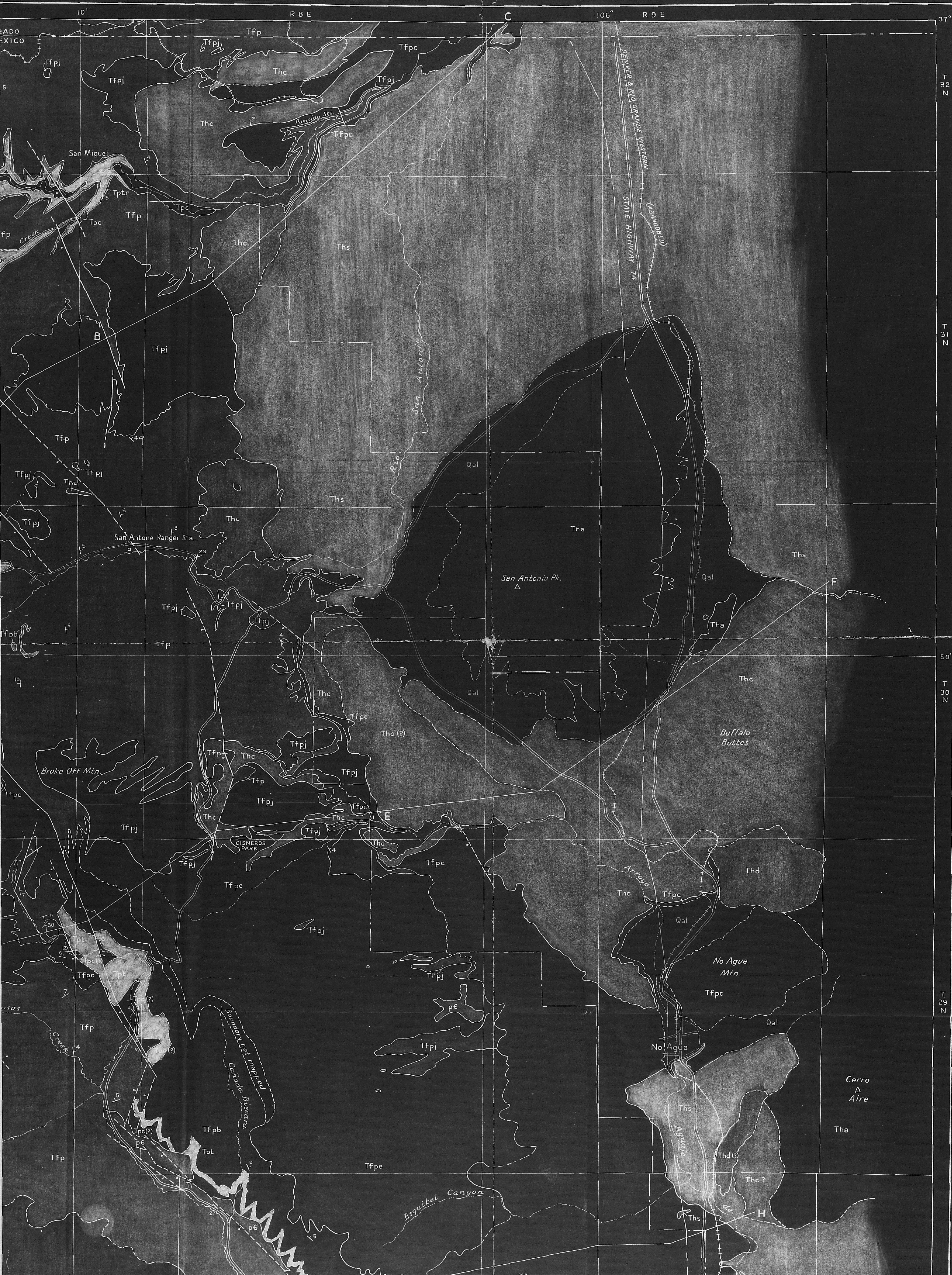
Scale in Miles

0 2 3 4 5

Base map compil
Commission fron

Geology by A. P
H. E. Wright, J.

37°
20'
R6E
R7E
10'
COLORADO
NEW MEXICO
Sublette
DENVER & RIO GRANDE WESTERN
Rio Los Pinos
San Miguel
Beaver Creek
Iola Creek
Rio San Antonio
San Antone Ranger
Broke Off Mtn.
Tusas Creek
A
B
D
Tptr
Tpc
Tfp
Tfpj
Tpt
pЄ
Qls
Qal
Thc
Tfpc
Tpc?
Tpc(?)


R8E
R9E
106°
C
T 32 N
T 31 N
T 30 N
T 29 N
50'
10'
Tfp
Tfpj
Tfpc
Thc
Ths
Tha
Thd
Thd (?)
Thc ?
Qal
Tpc
Tptr
Tpt
Tpc(?)
Tfpb
Tfpe
pЄ
Pumping Sta.
San Miguel
Creek
DENVER & RIO GRANDE WESTERN
(ABANDONED)
STATE HIGHWAY 74
Rio San Antonio
B
San Antone Ranger Sta.
San Antonio Pk.
F
Buffalo Buttes
Broke Off Mtn.
E
CISNEROS PARK
Arroyo
No Agua Mtn.
No Agua
Cerro Aire
Boundary not mapped
Cañada Biscara
Esquibel Canyon
Agua
H