EVALUATION OF AGGREGATE RESOURCES IN PART OF THE WEST HALF OF THE SANTA FE NATIONAL FOREST

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ABSTRACT

New Mexico Institute of Mining and Technology in cooperation with the U. S. Forest Service undertook a study of aggregate resources in the west half of the Santa Fe National Forest. The Forest Service outlined areas where needs were greatest and provided a priority ranking for each area to guide the study. Materials in adequate supply will be developed and used locally to construct or improve Forest routes for industrial and recreational use.

The west half of the Santa Fe National Forest encompasses approximately 1500 square miles of which 194 square miles were included in the 6 areas studied. Detailed geologic investigation identified four rock units as potential aggregate sources; listed in order of abundance these are:

1) Tertiary volcanics (Paliza Canyon Formation),
2) Pennsylvanian limestones (Madera Formation),
3) Cretaceous limestone (Greenhorn Limestone), and
4) Permian conglomerates (Cutler Formation).

However, the Madera Formation is the most widely distributed and is available in more areas; the Paliza Canyon Formation is limited to the southeastern part of the area. The predominant aggregate source west of Rio de las Vacas is Madera Formation with scattered small deposits of Permian Conglomerates and Greenhorn Limestone. East of Rio de las Vacas the thick series of Tertiary and Quaternary volcanics cover the older rocks and the Paliza Canyon Formation must be utilized where found.

SUMMARY AND CONCLUSIONS

The following areas are referred to the U. S. Forest Service as possible sources of aggregate for local access roads. The descriptions are based totally on geologic evidence existing in the field during the summers of 1978 and 1979. Estimates of tonnages are calculated below for the most favorable locality in each area using weight per cubic yard of crushed or broken limestone as 2,570 pounds (Lefond, 1975) and for basalt (volcanic rock) as 2,500 pounds per cubic yard.

Area #1 (Plate #1)

Locality #1 consists of the Greenhorn Limestone which forms a hogback near the Gallina River and Llaves, New Mexico. The hogback protrudes approximately 70 feet (21.3 m) above the Quaternary Alluvium in the lower elevations of area #1. The accessibility is excellent and it is hidden from view of most existing roads in the region. The vegetation is sparse consisting of low brush and a few Piñon Pines. Reclamation would be rather simple if adequate caution was exercised when reseeding the surface. If the hogback were completely removed to conform with the surrounding surface elevation, 158,570 tons of limestone could be extracted.

Area #2 (Plate #2)

Please refer to Aggregate Source Evaluation SW¼, sec. 33, T21N, R2E N.M.P.M., Cuba District of the Santa Fe National Forest, Rio Arriba County, New Mexico. This area seems to be an excellent source of aggregate. The report by F. M. Fox and Associates is quite accurate with one exception. The limestone being dealt with appears to be an upper unit of the Madera Limestone rather than a lower unit. This is quite apparent from relationships with the overlying Permian sediments as well as the lithologic relationships in the Madera Formation.

Area #3 (Plate #3)

Locality #1 in area #3 is comprised of a thick, massive flow basalt capping a mesa with altered pumice overlying it. The mesa has a healthy growth of Piñon-like trees with very little vegetation fit for grazing. It is flat and covers quite a large area, therefore a pit on the interior of this mesa would be nearly invisible to passing traffic. No streams or springs are common to the area therefore water contamination or aquifer interuption would not be a concern. The basalt unit contains no authigenic clays but the overlying pumice may yield enough clay to bring plasticity to standards. The access is very rough, but minimal improvement is all that would be required for temporary heavy duty access.

The tonnage over the entire mesa is immense. Rough calculations indicate a deposit capable of producing over 23,000,000 tons.

Area #5 (Plate #4)

Locality #1 consists of a thin- to medium-bedded limestone from the upper Madera Formation. It forms a plateau-like deposit near Forest Route 103. There is almost no vegetation, other than grass, present on this deposit, but care should be taken to preserve any available top soil. The surface is nearly horizontal therefore sloping of the pit walls would be required after abandonment. A year round spring is located on the southeastern margin therefore care must be taken to stay a sufficient distance from the active stream and aquifer. According to the dimensions seen on the surface this deposit is capable of yielding 178,470 tons of crushed gravel. Drilling should be implemented prior to development for the unit may be thicker than surface rocks reveal.

Area #6

No aggregate deposits were found and it is my opinion that none exist.

This is based on the fact that the Bandelier Tuff is present everywhere within the boundaries of the area.

Area #9 (Plate #5)

Only a short period of time was spent in area #9, therefore sources of aggregate may exist other than those mentioned in this report.

Locality #1 consists of a basalt unit at least 30 feet thick which occurs on a point separating two intermittent streams. It has a dense flora of Ponderosa Pine and scrub oak and may be visible from Forest Route 10. The basalt is nearly horizontal whereas the surface slope continues up at a gentle grade. This may prove harmful during extraction and greatly limit the size of the pit. Drilling should be considered to determine the lateral extent from which aggregate could be removed economically. Calculations using surface data indicate that there exists at least 20,830 tons of aggregate which has less than 5 feet (1.5 m) of overburden.

SANTA FE NATIONAL FOREST AGGREGATE STUDY

INTRODUCTION

The Santa Fe National Forest Aggregate Study was done at the request of the United States Forest Service through a contract with New Mexico Institute of Mining and Technology. Personnel from the Santa Fe National Forest selected several areas in the west half of the forest where road aggregate material is needed; fourteen areas were delineated and given relative priorities. This report deals with six of the areas of highest priority. Geological reconnaissance coupled with local detailed mapping identified areas which could satisfy the several criteria of local preparation, ready access, minimal transport, durability, and limited environmental impact. All materials were for construction of new roads and improvement of existing Forest Routes for recreation and industrial use.

Purpose and Scope

The purpose of this project was to locate and evaluate, considering surface conditions, rocks which could serve as local sources of aggregate in the western half of the Santa Fe National Forest. Approximately 1500 square miles of National Forest land with scattered private acreages are involved. In addition, Baca Location #1, Bandelier National Monument, San Pedro Parks Wilderness and a number of Spanish Land Grants are contained within the forest boundary. The Jemez, Zia, Santo Domingo, Cochiti and Santa Clara Indian Reservations form parts of the southern and eastern border, and the Jicarilla Indian Reservation bounds the forest on the north and west.

Accessibility

State highways traversing portions of the National Forest are, State Highway 4 through Jemez Springs, State Highway 96 through Gallina, State Highway

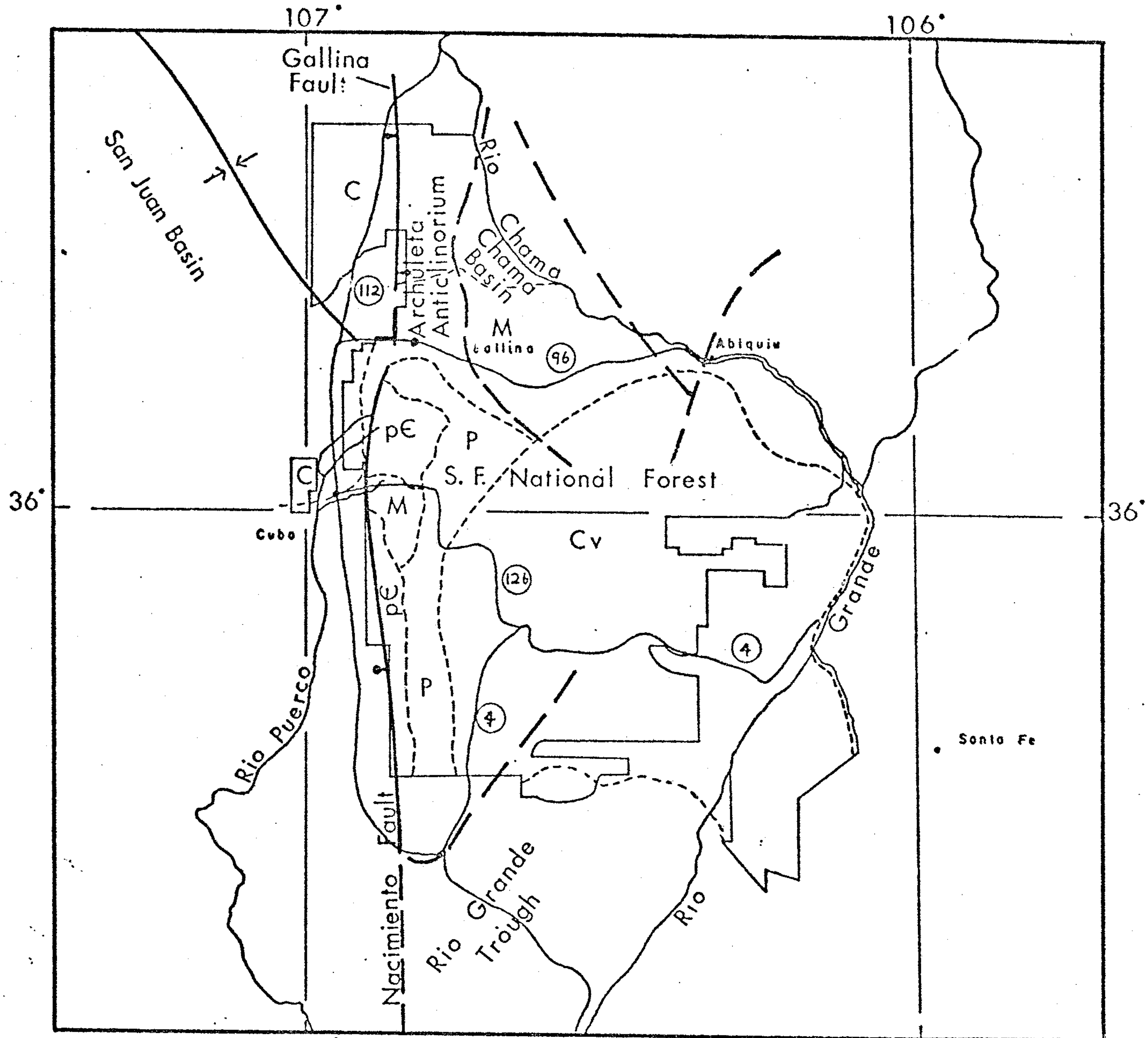
290 through Ponderosa, State Highway 126 through La Cueva and Fenton Lake and State Highway 112 through Llaves and Maestas. These are paved all-weather roads with the exceptions of State Highway 112 and State Highway 126 from Fenton Lake to Cuba. Forest Routes adjoining the state highways are numerous but should be considered fair weather roads as a general rule. These Forest Routes provide adequate access to most areas in the National Forest during the summer season (many are closed by snow during November-June) but caution should be exercised at all times when travelling such roads since summer thundershowers can make them impassable within a few minutes.

GEOLOGY

The west half of the Santa Fe National Forest contains a variety of rock types, of which only a few are suitable for aggregate. Knowledge of the general geology of the Forest simplifies study procedures considerably since unfavorable areas can be quickly eliminated.

The area includes several major tectonic provinces and structural features. Faults and folds, dating from Precambrian to Tertiary, involve crystalline, sedimentary and volcanic rocks. The descriptions of the regional geology are taken from the study of Rio Arriba County by Bingler, (1968); other contributors are cited when used.

The eastern part of the San Juan Basin province of the Colorado Plateau region occupies the western edge of the Santa Fe National Forest. The basin is bounded on the east by the Gallina fault zone and on the northeast by the broad, southern extension of the Archuleta Anticlinorium (see fig. 1). The Archuleta Anticlinorium is a series of irregular folded structures, so arranged, that they form a broad arch between the San Juan Basin and the Chama Basin. Along the western margin of the Gallina fault zone, sedimentary rocks from Pennsylvanian to Tertiary age dip westward, generally at steep angles, toward the



pЄ - Precambrian; P - Paleozoic; M - Mesozoic; C - Cenozoic. v - volcanics
---------- Geologic contact; ———— National Forest Boundary
basin axis; ⑤ State Highway

Figure 1: Location Map of West Half of Santa Fe National Forest.

central part of the San Juan Basin.

Along the east-central margin of the San Juan Basin from Llaves Post Office to T26N, the Gallina fault zone and the Archuleta Anticlinorium are connected by a much faulted anticlinal warp (The Gallina uplift). Faults along this arch are generally short rarely exceeding three miles of strike length. The northeast portion of the forest area includes the Chama Basin which is an elongate, generally north-plunging and -trending, shallow structural and topographic depression. It is believed to be a subsidiary extension of the San Juan Basin. The western boundary of the Chama Basin is defined by the much faulted Archuleta Anticlinorium to the north and the Gallina fault to the south. The southwestern portion of the Chama Basin merges with the San Pedro uplift which forms the northern end of the Nacimiento uplift. Folds within the Chama Basin are limited to numerous small domes and doubly plunging anticlines.

The Gallina uplift is a northern extension of the Nacimiento uplift. The Gallina uplift consists basically of three domal structures or doubly plunging anticlines formed over an eighteen mile fault. The fault separates the Chama and San Juan Basins and the folds include rocks of Permian to Jurassic age with one small area of Pennsylvanian rocks exposed in the core of the northernmost asymmetrical doubly plunging anticline near Forest Route 505.

The Nacimiento fault extends south from the southern end of the Gallina fault to west of San Ysidro (see fig. 1). Displacements have lifted Precambrian crystalline rocks of the Nacimiento and San Pedro uplifts and thrust them westward over the Cretaceous beds of the San Juan Basin. The northern terminus of the Nacimiento fault seems to swing northeast toward the settlement of Gallina.

The Rio Grande Trough is the major tectonic element of the southeastern part of the forest area. It is about 30 miles wide extending from west of Abiquiu to the Sangre de Cristo Mountains. The southwestern margin of this trough-like structure emerges from beneath the late Tertiary volcanic rocks of the Jemez Mountains about five miles west of Abiquiu.

Rocks in the western half of the Santa Fe National Forest range from Precambrian crystalline rocks through Paleozoic, Mesozoic and Cenozoic sediments to Cenozoic volcanics.

Precambrian rocks are best developed south of San Pedro Mountain and contain a wide variety of coarse- to fine-grained metamorphic types. Metavolcanics, hornblende gabbro and diorite, quartz diorite, hybrid porphyry, and quartz monzonite are represented (Woodward, McLelland and Kaufman, 1971). They crumble readily on exposed surfaces and crop out with a rounded blocky appearance.

Sedimentary Rocks

The oldest Paleozoic sediments are Mississippian in age. Only rare local exposures are found either due to nondeposition over much of the area or pre-Pennsylvanian erosion. The Mississippian rests unconformably on Precambrian terrain. The Mississippian on San Pedro Mountain is assigned to the Arroyo Peñasco Formation and consists of a basal sandstone with overlying fossiliferous limestones some of which are dolomitic (Armstrong, 1967).

Rocks of Pennsylvanian age unconformably overly the Mississippian or rest on Precambrian layers. The Pennsylvanian rocks are arkosic sandstones, shales, limestones and clastic limestones. The thickness varies rapidly from 400-500 feet (121.92-152.4 m) near Mining Mountain to 1800 feet (584.6 m) at the north end of the Nacimiento fault (see fig. 1). An abundant fauna of crinoid fragments, bryozoa, brachiopods, pelecypods, gastropods and fusulinids is present in the limestone and clastic limestone beds. Although detailed zoning was not attempted, equivalents of the Sandia and Madera Formations are present.

The Permian system consists of continental red shale and sandstone and is assigned to the Cutler Formation; these Cutler red beds probably include equivalents of the Abo, Yeso and San Andres Formations. The Cutler formation rests unconformably on Madera limestone in most places. The sandstones are coarse-grained (locally conglomeratic) commonly arkosic, and often crossbedded. The average thickness over the forest area is 400 feet.

The Triassic system is composed of a lower sandstone member (Agua Zarca Member) and an upper shaly mudstone and siltstone member of the Chinle Formation. Although other local members (Salitral shale, Poleo Sandstone) are recognized (Northrop and Wood, 1946) they are not sufficiently extensive or persistent to merit consideration in this study. The lower contact of the Chinle Formation is unconformable with the older Cutler Formation. The Agua Zarca sandstone member consists of gray-white to brown to yellowish-brown, fine- to medium-grained, massive to crossbedded sandstone interbedded with discontinuous conglomerate layers. The upper shale member grades from thin-bedded shaly sandstone near the base to even-bedded shale over most of its thickness. The color ranges from reddish-brown to purplish-red. In the forest area the Chinle is approximately 650 feet (189.1 m) thick.

The Jurassic system involves three formations, the Entrada, Todilto and Morrison.

The Entrada Formation consists of tan to pinkish-tan to white, well-sorted crossbedded sandstone with an average thickness of 200 to 250 feet (60.9-76.2 m). The lower contact with the Chinle is everywhere sharp and slightly unconformable.

The Todilto Formation is a thin, persistent sequence of limestone, calcareous shale and gypsum. The thickness commonly ranges from 0 to 25 feet (7.62 m) near the eastern border of the San Juan Basin, although local thicknesses of nearly 100 feet (30.48 m) of gypsum are found at Gallina and near Echo Amphitheater (Smith, Budding and Pitrat, 1961).

The Morrison Formation includes gray to pinkish-white sandstone interbedded with green or red mudstone, banded green and orange mudstone and red claystone. The overall color appears to grade from predominantly pinkish-tan at the base to pinkish-green at the top. The basal contact is irregular and the thickness averages about 600 feet (182.9 m).

The Cretaceous system is composed of a number of formations with the youngest units being transitional Cretaceous-Tertiary deposits. The Dakota Formation (lower upper Cretaceous) unconformably overlies the Morrison Formation (Smith, Budding and Pitrat, 1961). The Dakota Formation crops out as a lower sandstone, a middle carbonaceous shale and an upper sandstone. The sandstones are similar consisting of pale-orange to yellowish-brown, chert-bearing quartz sandstone which is partially crossbedded (Smith, Budding, and Pitrat, 1961). The middle shaly sequence contains dark-gray, fissile, carbonaceous shale with lenses of coal and platy even-bedded silty sandstone.

The Dakota grades upward into the Mancos shale which consists of the Graneros Shale Member, the Greenhorn Limestone Member and an upper shale Member (Carlile and Niobrara).

The Graneros shale consists of about 120 feet (36.6 m) of dark-gray to black, thin-bedded, fissile sandy shale. The gradational contact with the Dakota is marked by a decrease of thin sandstone layers into a predominantly shale sequence.

The Greenhorn limestone is approximatley 35 feet (10.7 m) of thin-bedded dark-gray limestone and greenish-gray shales. The limestone comprises approximately 50% of the member and fractures into sliver-like fragments.

The upper shale member includes dark-gray to light yellowish-tan shale, mudstone and claystone. The thickness is approximately 1800 feet (548.6 m) and comprises the bulk of the Mancos Shale.

The Mesaverde Group overlies the upper shale member of the Mancos Formation and consists of three units, the Point Lookout Sandstone, the Menefee Formation and the Cliff House Sandstone (Baltz, 1967).

The Point Lookout Sandstone reaches 240 feet (73.2 m) in thickness and is thick-bedded, massive, fine- to medium-grained, olive-gray to tan, friable arkosic sandstone. The medial Menefee Formation consists of interbedded, gray-black and purple, siltstone and shale, coal and gray to white crossbedded sandstone. The Cliff House Sandstone includes 30 to 80 feet (9.1 to 24.4 m) of very fine-grained, thin-bedded, orange sandstone interbedded with gray shale.

Overlying the upper sandstone beds of the Cliff House Sandstone is nearly 2000 feet (609.6 m) of dark-gray, calcareous and arenaceous shale. This unit has been correlated with the Lewis shale.

Up to 100 feet (30.48 m) of undifferentiated upper Cretaceous rocks often occur as wedges between the Lewis shale and younger Cretaceous-Tertiary sediments (Baltz, 1967). They contain a basal, white, medium-grained quartz sandstone (Pictured Cliffs Sandstone?) and an upper dark-green to black shale (Kirtland-Fruitland Formation?) with interbedded brown and white sandstone.

Unconformably above the undifferentiated shale and sandstone lies the Ojo Alamo Sandstone. This consists of 70 to 170 feet (21.3 to 51.8 m) of pale yellowish-tan and brown, medium- to coarse-grained sandstone interlayered with thin lenses of olive-green shale (Baltz, 1967). Crossbedding is widespread and conglomeratic sandstones containing pebbles of felsite are often encountered.

The Nacimiento Formation conformably overlies the Ojo Alamo and reaches a maximum thickness of 1750 feet (533.4 m)(Baltz, 1967). The basal part is thick, fine- to coarse-grained sandstone and interbedded olive-green to gray carbonaceous shale. The middle consists of shale with thin lenticular green shale beds and the upper part is a cliff-forming conglomeratic, coarse-grained, arkosic sandstone interbedded with shale.

The youngest sedimentary rock in the forest area is the Tertiary San Jose Formation. This formation consists of nearly 2000 feet (609.6 m) of intertongued gray, tan and reddish-brown sandstone and conglomerate, and variegated gray and red shale.

Quaternary terrace gravels and recent alluvium fill the broader valleys. Locally, the gravels consist of well rounded pebbles, cobbles, and boulders of Precambrian quartzite, crystalline rocks, and subordinate volcanic rocks deposited by the major drainage systems of the area.

Igneous Rocks

In approximately the center of the west half of the Santa Fe National Forest, centered at the Baca Location #1 and thinning radially in all directions, lies the volcanic complex of the Jemez Mountains. The rocks of this complex are Tertiary-Quaternary in age and overlie an erosional surface on the Paleozoic, Mesozoic and Cenozoic sediments. The volcanics have widely varying compositions and thicknesses and comprise a major portion of the forest area.

The earliest igneous episode (early Tertiary) deposited basaltic, andesitic and dacitic flows and tuff breccias which were intruded by small stocks, dikes and sills of granodiorite. The thickness is unknown (Smith, Bailey and Ross, 1970).

A later igneous event erupted the Abiquiu Tuff which ranges from 0 - 1200 feet (365.8 m) thick and is mainly white to light-gray tuffaceous sand and conglomerate. It includes a basal conglomerate member with fragments of Precambrian crystalline rocks and a thin chert bed (Smith, Bailey and Ross, 1970).

Following the deposition of the Abiquiu Tuff, a thick series of flows, tuffs, and domes of varying compositions were emplaced; vitric to lithoidal rhyolite, porphyritic dacite, rhyodacite, quartz latite and hypersthene-augite andesite are the principal rock types. Up to 7500 feet (2286 m) of material was deposited during this time (Smith, Bailey and Ross, 1970).

Continued volcanic activity added 3600 feet (1097.3 m) of olivine augite and titaniferous augite basalt, coarsely porphyritic dacite, rhyodacite, and quartz latite, as well as rhyolite domes and pumice cones.

During late Tertiary and Quaternary time the Toledo and Valles Calderas exploded and collapsed giving rise to nonwelded to densely-welded rhyolite ash flows and pumice of the Bandelier Tuff (0 → 2400 feet)(731.5 m), and a complex accumulation of intrusive and extrusive rhyolite, quartz latite and glass domes, flows, breccias, ash and tuff at least 4250 feet (1295.4 m) thick (Smith, Bailey and Ross, 1970).

AGGREGATE QUALITY GEOLOGIC UNITS

Scattered throughout the stratigraphic section are a few units favorable for use as aggregate material.

The lowest stratigraphic unit which has potential for aggregate use is the Pennsylvanian. The Pennsylvanian rocks are commonly quartz sandstone, arkose, clastic limestone, fossiliferous limestone and shale. The only favorable units in the Pennsylvanian for aggregate material are the fossiliferous limestones. These limestones range in thickness from 1 to 50 feet (.3048 to 15.24 m) but their lateral continuity is poor. A 50 foot (15.24 m) limestone bed may thin to less than 20 feet (6.1 m) in less than one mile. Individual layers range from thin (5-10 cm) to very thick (100 cm plus) and are commonly nodular in the thinner units. Many of the beds are separated by thin to medium (10-30 cm) shale partings which make up 5% to 60% of the rock unit. As a general rule where thick units of shale are observable and overlain by limestone, there is a transition from shale to nodular limestone to massive limestone. The limestone is fine- to coarse-grained calcite and/or dolomite with scattered zones containing chert. The chert is found as pods or nodules on the bedding planes of the limestone and contains depositional structures and fossils of the same type as those found in the limestone. Also chert is found in joints and thus appears to have been remobilized and deposited along the fracture planes. The limestones contain whole forms as well as fragments of bryozoa, crinoids, brachiopods, pelecypods, gastropods, and fusulinids, any of which may have their tests replaced with fine-grained silica or chert. The limestone weathers light-gray to dark-purple and commonly parts along bedding planes and joints. Often the limestone contains sand grains of varying composition, size and abundance but this often decreases the abrasive strength of the material; therefore, excessively sandy limestones were not considered.

Directly above the Pennsylvanian system is the Permian or Cutler Formation. This formation is about 400 feet (121.9 m) thick and is considered the lateral equivalent of the Abo, Yeso, and San Andres formations exposed farther south. The Cutler is commonly a brownish-gray to greenish-gray arkosic sandstone inter-bedded with brownish-red shale. It exhibits well-defined crossbeds and may be crumbly or very hard and well-cemented in outcrop. The majority of the Cutler is useless as aggregate material but intermittently beds of conglomerate are found. These conglomerates are interbedded with light yellowish-brown arkose and greenish-gray siltstone. These conglomeratic zones display very poor later-al continuity and often the only evidence of their existence is the residual pebbles lying on the surface. The conglomerate zones range from 0 to 14 feet (4.3 m) thick with approximately 30% of the zone being conglomeratic. The peb-bles are commonly quartzite, granite or gneiss, well rounded and are from 3 in. to 7 in. (.076 to .178 m) in diameter. These pebbles comprise about 30% of the rock and are surrounded by poorly sorted arkose.

The Triassic and Jurassic rocks lack adequate thickness, favorable rock type or both.

The Cretaceous Greenhorn Limestone overlies the Graneros Shale Member of the Mancos Shale and underlies the upper shale member. The Greenhorn is 20-60 feet (6.1 to 18.3 m) of alternating beds of gray dense limestone and darker gray calcareous shale. Outcrops are relatively conspicious because of its greater erosional resistance as compared to the overlying and underlying shales. Both the limestone and associated shale of the Greenhorn weather to a white or whitish-gray color which strikingly contrasts with the overlying and underlying beds. Although outcrops appear dense and massive the limestone is generally fractured into slivers and chips. The limestones and shales are commonly found in equal measures but the limestone is the most observable in the field. Care should be exercised when dealing with the Greenhorn limestone for its thickness and limestone content may vary markedly along the strike.

The youngest rock type which has adequate aggregate properties is a part of the Jemez Mountains volcanic pile. The Paliza Canyon Formation of Tertiary age as defined by Smith, Bailey and Ross (1970) ranges from 0-2800 feet (853.4 m) thick and was deposited while the Valles Caldera was active. The Paliza Canyon Formation consists of coarsely porphyritic dacites, rhyodacites and quartz latites containing pyroxene, hornblende, biotite and occasional quartz phenocrysts in the upper 800 feet (243.8 m) and andesites, basalts, flow breccias and tuff breccias in the lower portion of the formation. It is common to find thick units of basalt capping mesas with a small amount of uneroded tuff scattered on top. The basalts and andesites commonly form very prominent cliffs and break into large angular boulders. At times the rocks are very vesicular near the base but the vesicularity decreases upward.

Methodology

The criteria by which aggregate quality rocks were evaluated are based on quantity, quality, extractability, accessibility and the environmental impact of the necessary quarries.

The rock must be dense, hard and able to withstand prolonged wear by heavy traffic as well as be inert to varying weather conditions. It should be within a reasonable distance of an established access road and adequate room should be allowed for preparation equipment (i.e., crusher, haulage trucks, etc.). The rock must have a minimum thickness of 10 feet (3.05 m) and desirably no more than 5 feet (1.5 m) of overburden. It should be, if possible, beyond the view of passing traffic from any distance and if not it must be possible to reclaim the disturbed surface to a condition as good or better than what previously existed. There should be an adequate quantity of rock in any one place (at least an acre) so that a minimum of 20,000 tons of material is available.

The recommendations herein consider these parameters, and are based solely on field observations; therefore the quantity and quality of the materials are estimates from surface exposures with reasonable geologic extrapolations.

AREAS EVALUATED

The first locality described within each area represents the most favorable aggregate source; subsequent localities are of less value.

Area #1 (Plate #1)

Area #1 is highly irregular and lies near the southeast corner of the Jicarilla Apache Indian Reservation (see Plate 1). Access to this area is principally from State Road 112 approximately one mile north of Llaves, New Mexico. The area encompasses approximately 75 square miles of National Forest with scattered private acreages. Forest Routes 3, 5, 6, 7, 312, 313, 505, 507, 508, 509, 514, and 515 reach within a few miles or less of any point in the area. Most of the area is covered with a dense growth of pine, fir and grasses.

The units in this area which may be of some value as aggregate are the Cutler Formation (Permian) and the Greenhorn Limestone Member of the Mancos shale (Cretaceous).

Locality #1 is eastnortheast of Llaves and north of where the Rio Gallina flows eastward 8 miles above its confluence with the Rio Chama (SE¼, SE¼, sec. 15, T25N, R1E and SW¼, SW¼, Sec. 14, T25N, R1E)(Fig. 2 and 3). The Greenhorn Limestone Member crops out as a hogback and consists of approximately 35 feet (10.67 m) of thinbedded limestone interbedded with light-greenish gray shales (Photo #1). The limestone comprises roughly 50% of this thickness and commonly fractures into sliver-like fragments (Photo #2). The hogback is approximately 980 feet (298.7 m) long by 400 feet (121.9 m) wide along the dip of the beds. This outcrop should provide 158,578 tons of relatively fine grained aggregate with maximum overburden of less than 10 feet (3.05 m).

In locality #2 the Cutler Formation contains a bed of conglomerate with a strike length of approximately 3500 feet (1066.8 m)(center, sec. 29, T26N, R2E)(Fig. 4). This bed varies from 8 feet (2.44 m) to 14 feet (4.27 m) thick in the few outcrops observed. The conglomerate commonly crops out on the crest of a symmetrical ridge 50 feet (15.2 m) in width. The pebbles are commonly quartzite (Photo #3). More than 10,000 tons of aggregate are available but quarrying would require a single narrow slot fifteen to thirty feet wide over one half-mile in length on a 10% slope.

Area #2

Area #2 encompasses approximately 13 square miles along the Rio Arriba-Sandoval County line near the southeast corner of the San Pedro Parks Wilderness area (see Plate II). Access is along State Road 126 from Cuba, New Mexico and Forest Routes 69, 70, 103, 117, and 527. Pennsylvanian limestone is the most likely source of aggregate in this area.

Locality #1 is accessible along Forest Route 527 and lies in the SW¼, Sec. 33, T21N, R2E (Photo #4). An aggregate evaluation has been done by F. M. Fox and Associates, Inc. on this area. Please refer to Aggregate Source Evaluation

Figure 2.

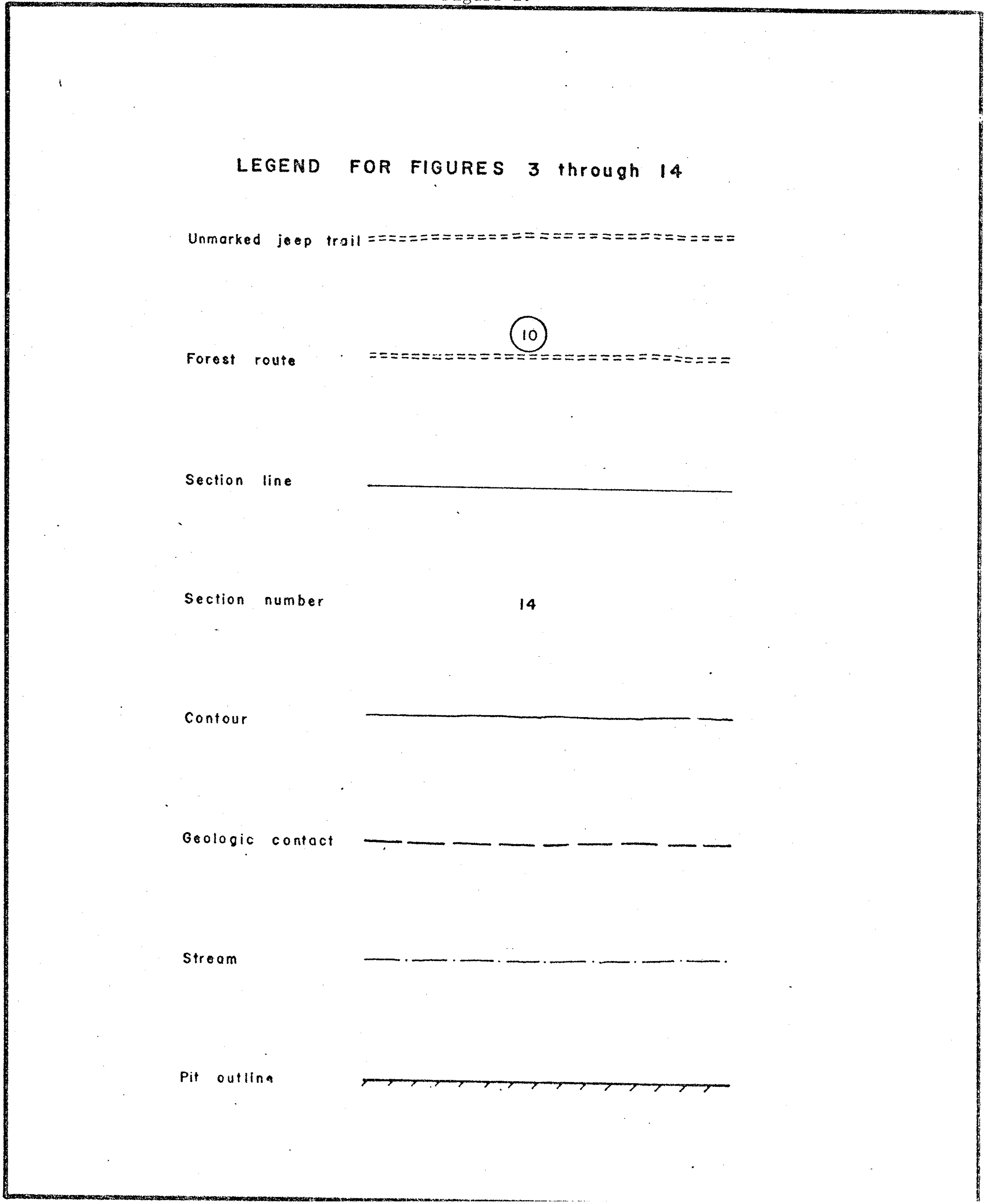

LEGEND FOR FIGURES 3 through 14
Unmarked jeep trail
10
Forest route
Section line
Section number
14
Contour
Geologic contact
Stream
Pit outline

Figure 3.

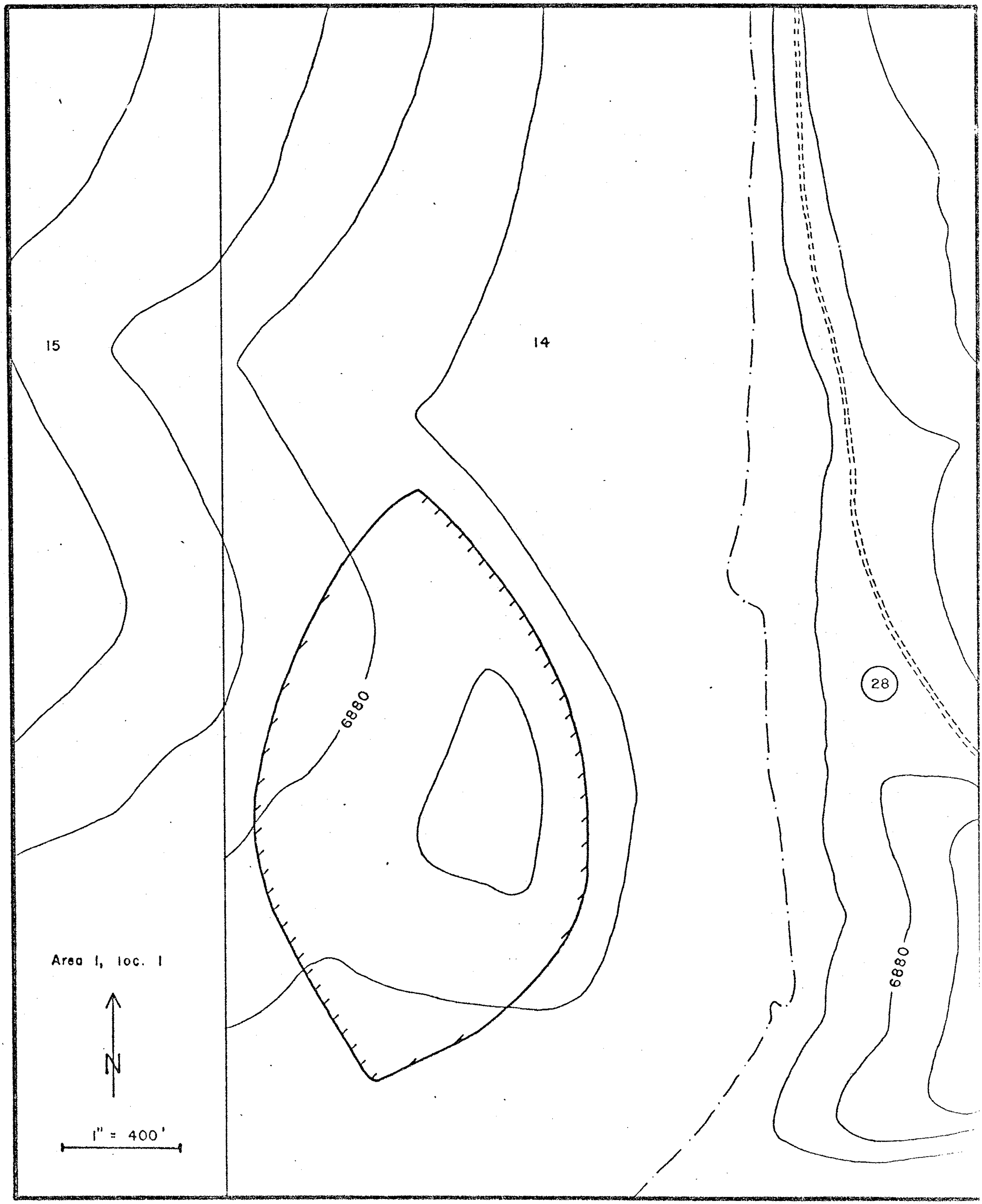


Photo #1. Hogback of Greenhorn limestone east northeast of Llaves in area #1, locality #1.

Photo #2. Limestone bed of the Greenhorn Limestone showing sliver-like fracturing (Photo taken on hogback in Photo #1).

Figure 4.

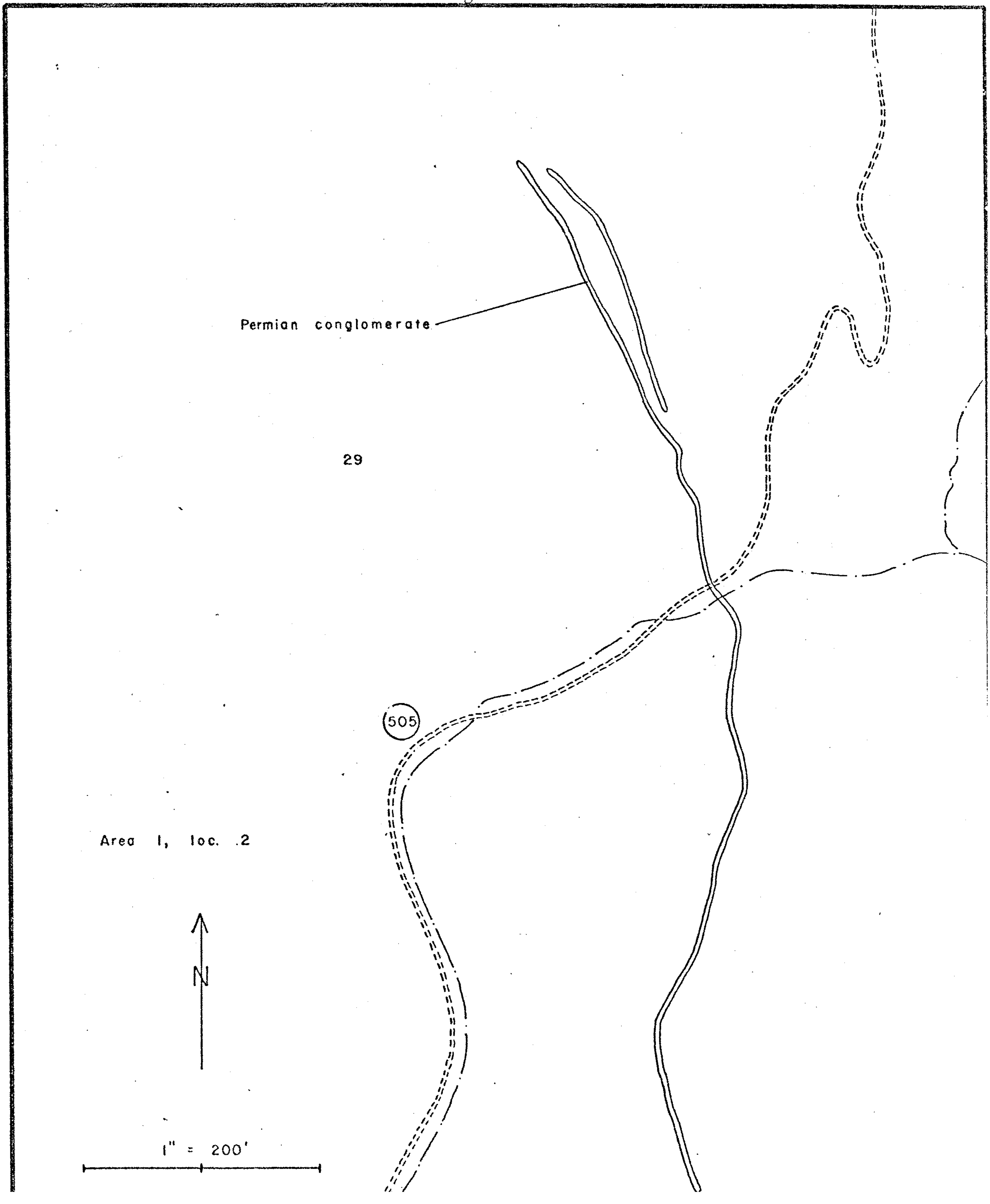


Photo #3. Conglomerate in the Cutler Formation (Permian) near Poso Springs in area #1, locality #2.

Photo #4. Limestone unit in the Madera Limestone (Pennsylvanian) on Forest Route 103 in area #2, locality #1.

SW¼, sec. 33, T21N, R2E N.M.P.M., Cuba District of Santa Fe National Forest, Rio Arriba County, New Mexico for pit plan and estimated tonnage.

Locality #2 is on the north side of Forest Route 527 near its junction with Forest Route 69 (N½, N½, NW¼, sec. 6, T20N, R2E, and S½, SW¼, Sec. 31, T21N, R2E)(Fig. 5). This limestone unit is 6.0 feet (1.8 m) to 10 feet (3.1 m) thick with lateral dimensions roughly 500 feet (152.4 m) square. It consists of a medium bedded fossiliferous limestone with a few chert nodules, forming a plateau-like feature on the east ridge of American Creek and adjoining tributaries (Photo #5 and #6). The top of the ridge is covered with a healthy population of young Ponderosa Pine. The overburden is everywhere less than 10 feet (3.04 m) thick and the tonnage of coarse to medium grained crushed aggregate is at least 92,000 tons.

In locality #3 (Fig. 6) the Pennsylvanian limestone crops out nearly horizontally on the north ridge of Rock Creek and south of Forest Route 527 (S½, NW¼ and N½, SW¼, sec. 6, T20N, R2E, and SE¼, NE¼ and NE¼, SE¼, sec. 1, T20N, R1E)(Photo #7). This unit is thin- to medium-bedded nodular limestone with very thin shale seams (Photo #8). It ranges from 8 feet (2.4 m) to 14 feet (4.27 m) thick and the surface dimensions are 500 feet (152.4 m) square. The overburden is 5 feet (1.52 m) thick near the outcrop, but within 100 feet (30.5 m) thickens to 20 feet (6.1 m). There is an existing quarry in this area where a small amount of aggregate has been taken. The vegetation consists of a sparse population of Ponderosa Pine. The estimated tonnage available with less than 5 feet of overburden is approximately 13,000 tons of crushed medium-grained limestone.

Area #3

Area #3 lies north of Ponderosa, New Mexico and southeast of San Juan Mesa and includes roughly 30 square miles (see Plate III). A portion of the Jemez

Figure 5.

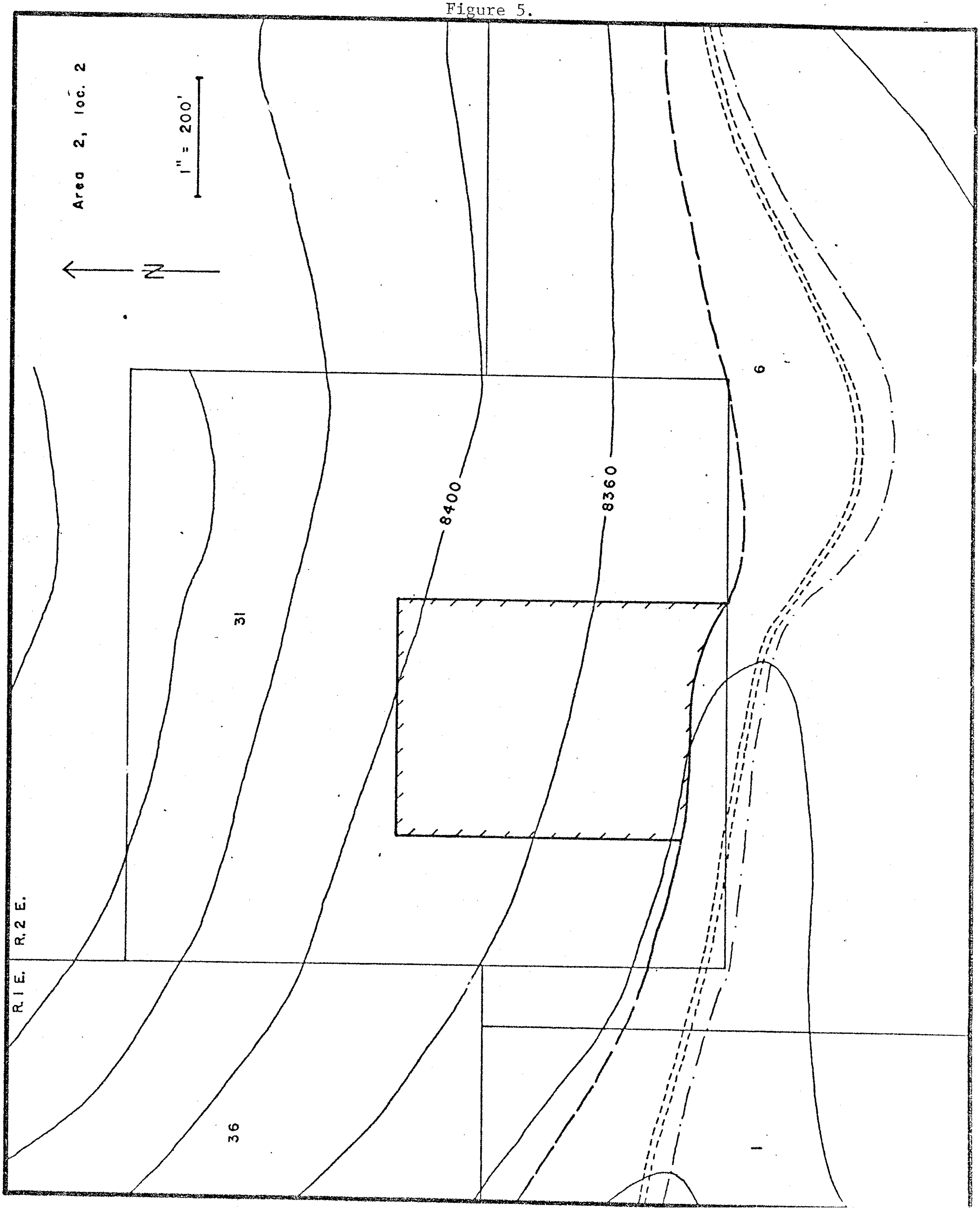


Photo #5. Tree covered plateau-like feature capped with Madera Limestone (Pennsylvanian) in area #2, locality #2.

Photo #6. Outcrop of limestone on top of plateau-like feature in photo #5 in area #2, locality #2.

Figure 6.

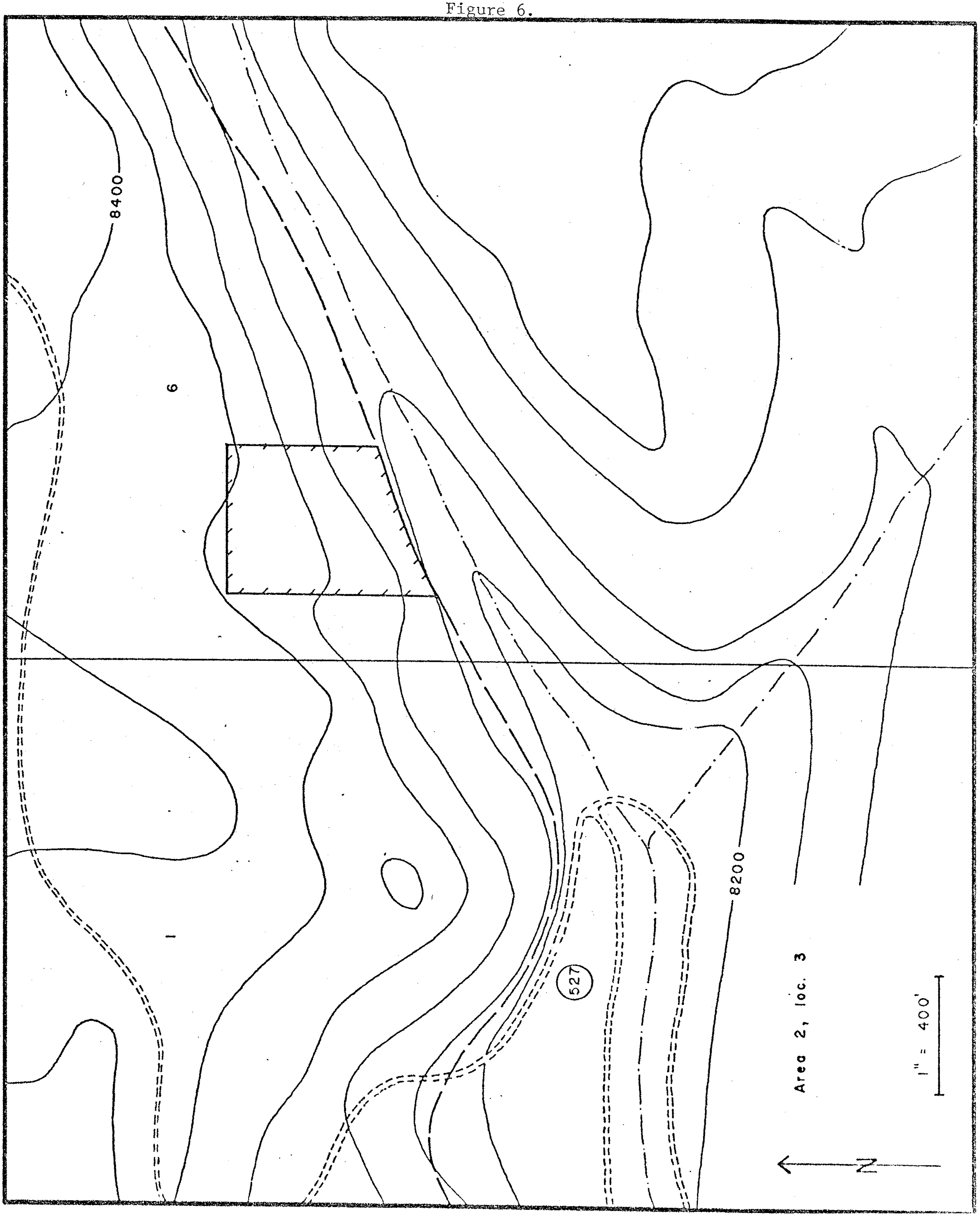


Photo #7. Plateau capped with Madera Limestone. Eroded banks in the foreground are from Rock Creek (area #2, locality #3).

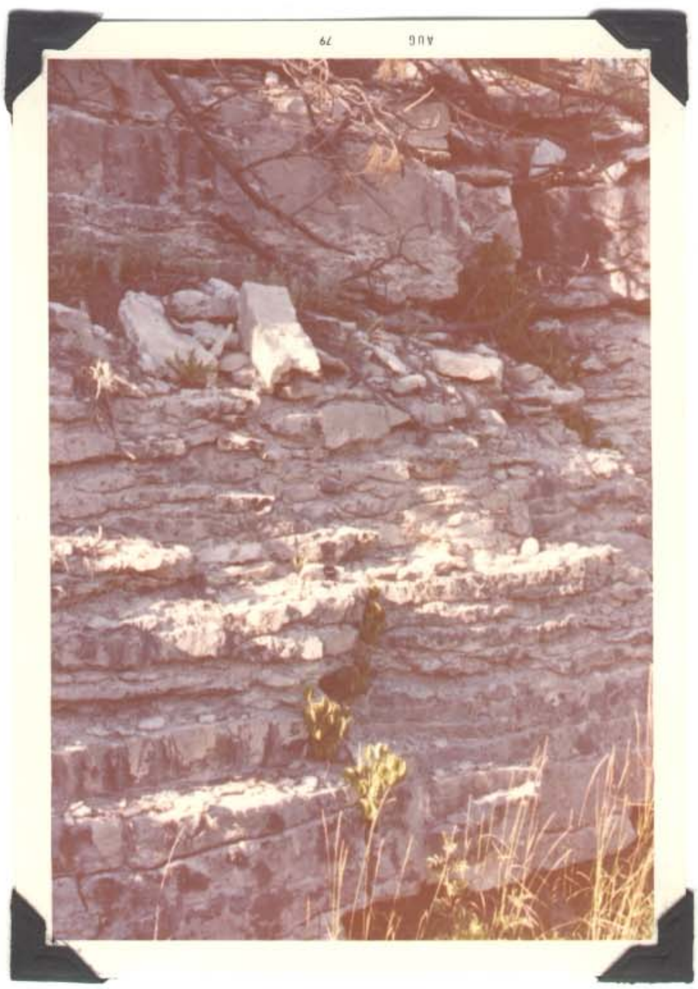


Photo #8. Closeup of Madera limestone caprock in photo #7. 50mm lens cap for scale is just below center of photo. (area #2, locality #3).

Indian Reservation lies in this area but was not considered as a possible source of aggregate. The area is accessible by State Road 290 through Ponderosa and secondary roads include Forest Routes 10, 137, 139, 266, 269, 271, 490, and 491.

Permian sediments crop out at the base of the north ridge near Paliza campground but no suitable conglomerate was located. The remaining portion of the area is covered primarily with Tertiary volcanics. The most suitable of these volcanics is basalt from the Paliza Canyon Formation. The best exposure of this basalt is on the west ridge of Borrega Canyon (Locality #1)(E½, Sec. 34, and W½, sec. 35, T17N, R3E)(Fig. 7). The basalt occurs as a horizontal caprock which is partially overlain by a thin veneer of what may be the Bearhead Tuff (Photo #9). The unit is approximately 100 feet (30.5 m) thick with lateral dimensions of 2500 feet (762 m) and 2000 feet (609.6 m). The overburden ranges from 0 to 20 feet (6.1 m) which is predominantly weathered tuff. Access is gained along Forest Route 137 and ends as a jeep trail for the final ½ mile. The tonnage estimate of the entire area is 23,148,000 tons.

Locality #2 (Fig. 8) is on the south ridge of Paliza Canyon, capping two mesa-like features (S½, SE¼, sec. 2, and N½, NE¼, sec. 11, T17N, R3E)(Photo #10). The eastern-most location is approximately 50 feet (15.2 m) thick by 1000 feet (304.8 m) by 2000 feet (609.6 m) and the western-most is approximately 1500 feet (457.2 m) by 800 feet (243.8 m). This area is covered with a dense growth of Ponderosa Pine and the overburden is quite variable except near the margins where it is essentially absent (Photo #11). This area is inaccessible to vehicles but a cleared access does exist to the top of the easternmost area. Moderate improvement of this road is necessary for heavy duty traffic. The estimated tonnage of crushed basalt aggregate with less than 5 feet of overburden is 1,157,400 tons.

Locality #3 is near the access road to an old pumice strip mine (SW¼, NW¼, sec. 10, T17N, R3E)(Fig. 9). It is roughly ¼ mile northeast from Paliza

Figure 7.

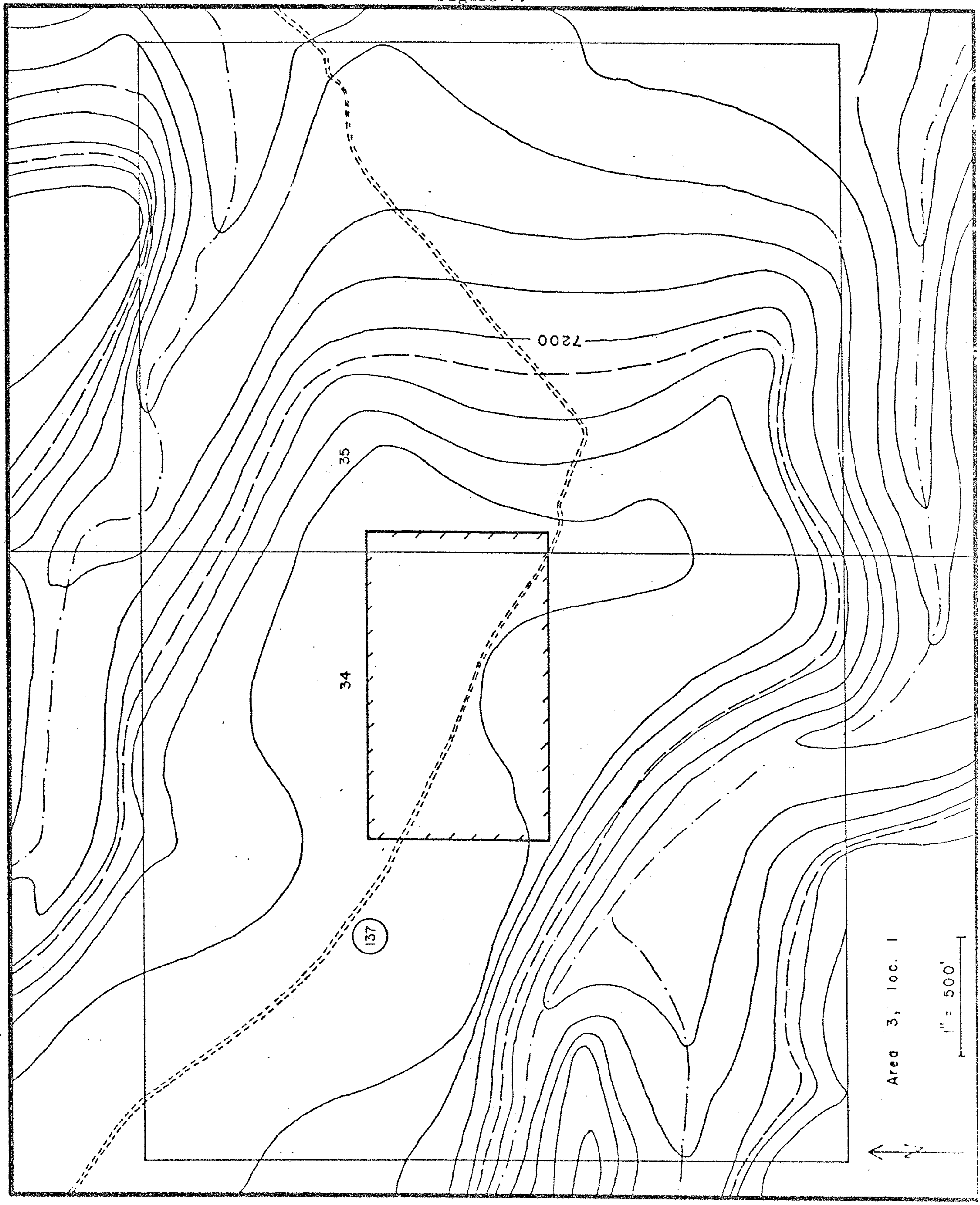


Photo #9. Basalt of the Paliza Canyon Formation on the west ridge of Borrego Canyon in area #3, locality #1.

Photo #10. Two Mesa-like features capped with basalt. (Paliza Canyon Formation) on the south ridge of Paliza Canyon (area #3, locality #2).

Figure 8

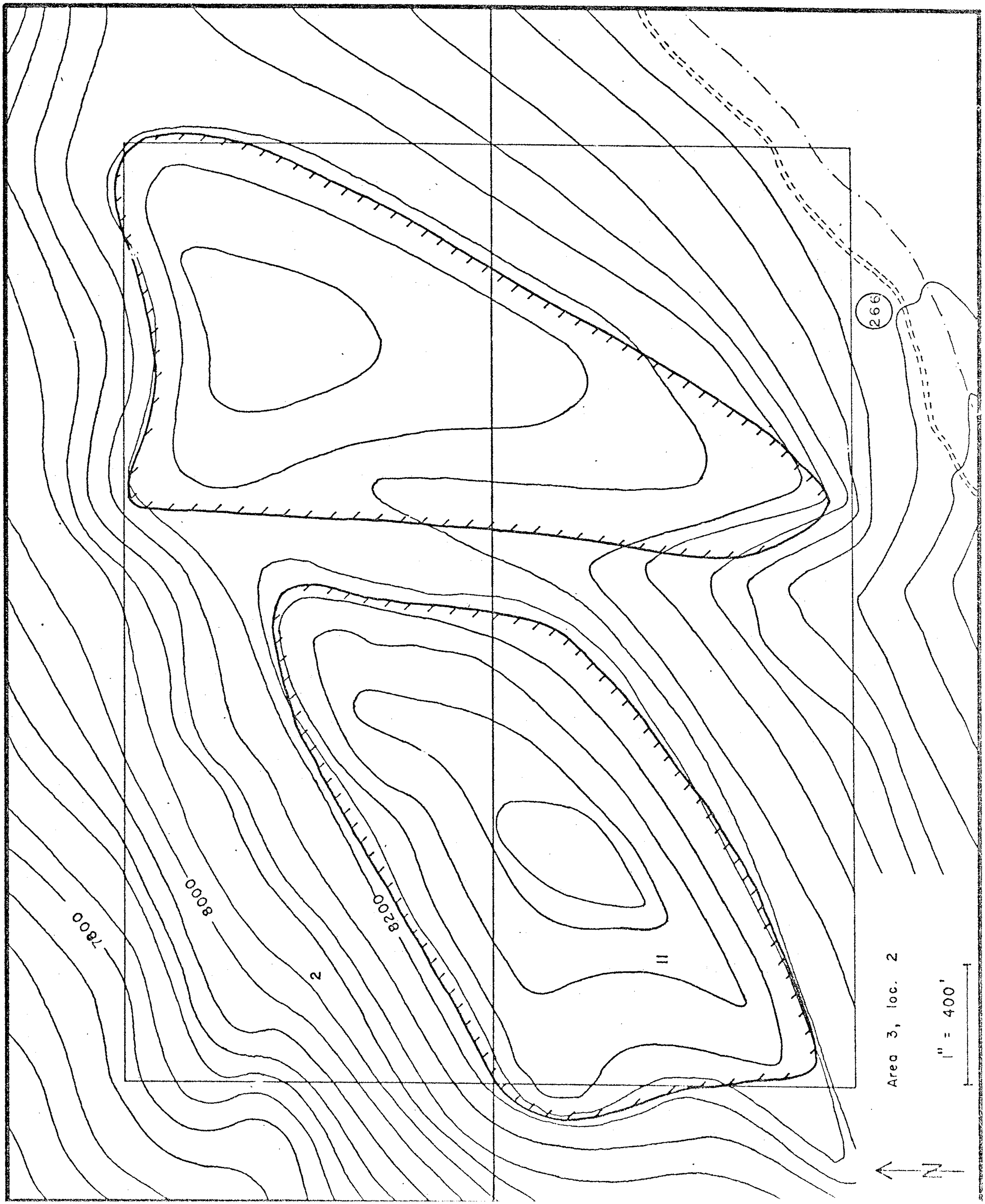


Photo #11. Outcrop of basalt referred to in photo #10 (area #3, locality #2).

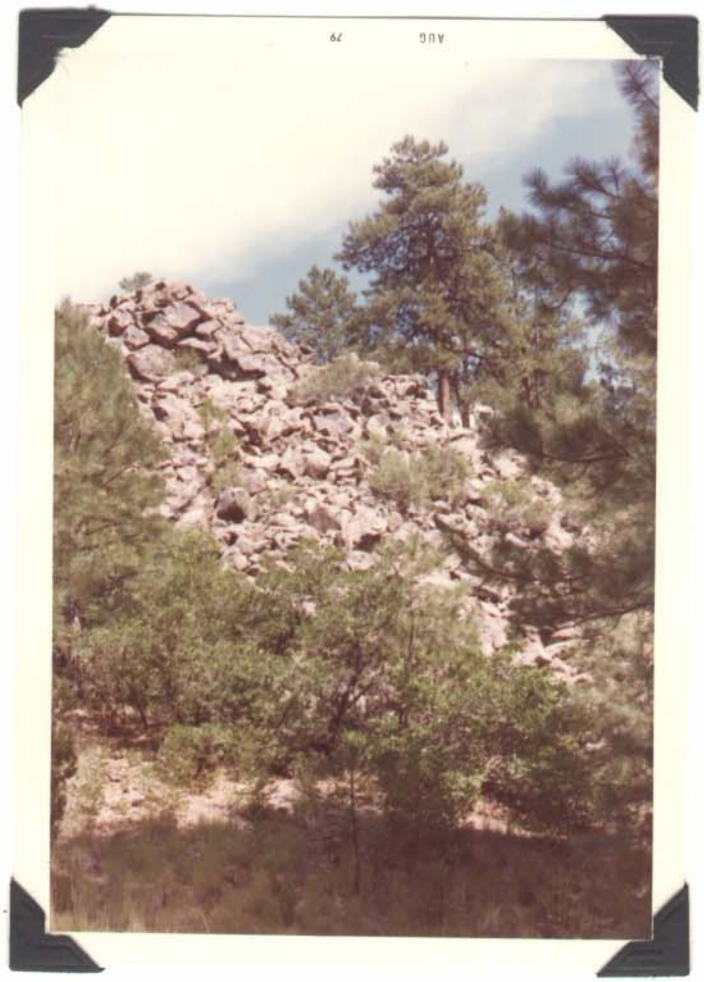
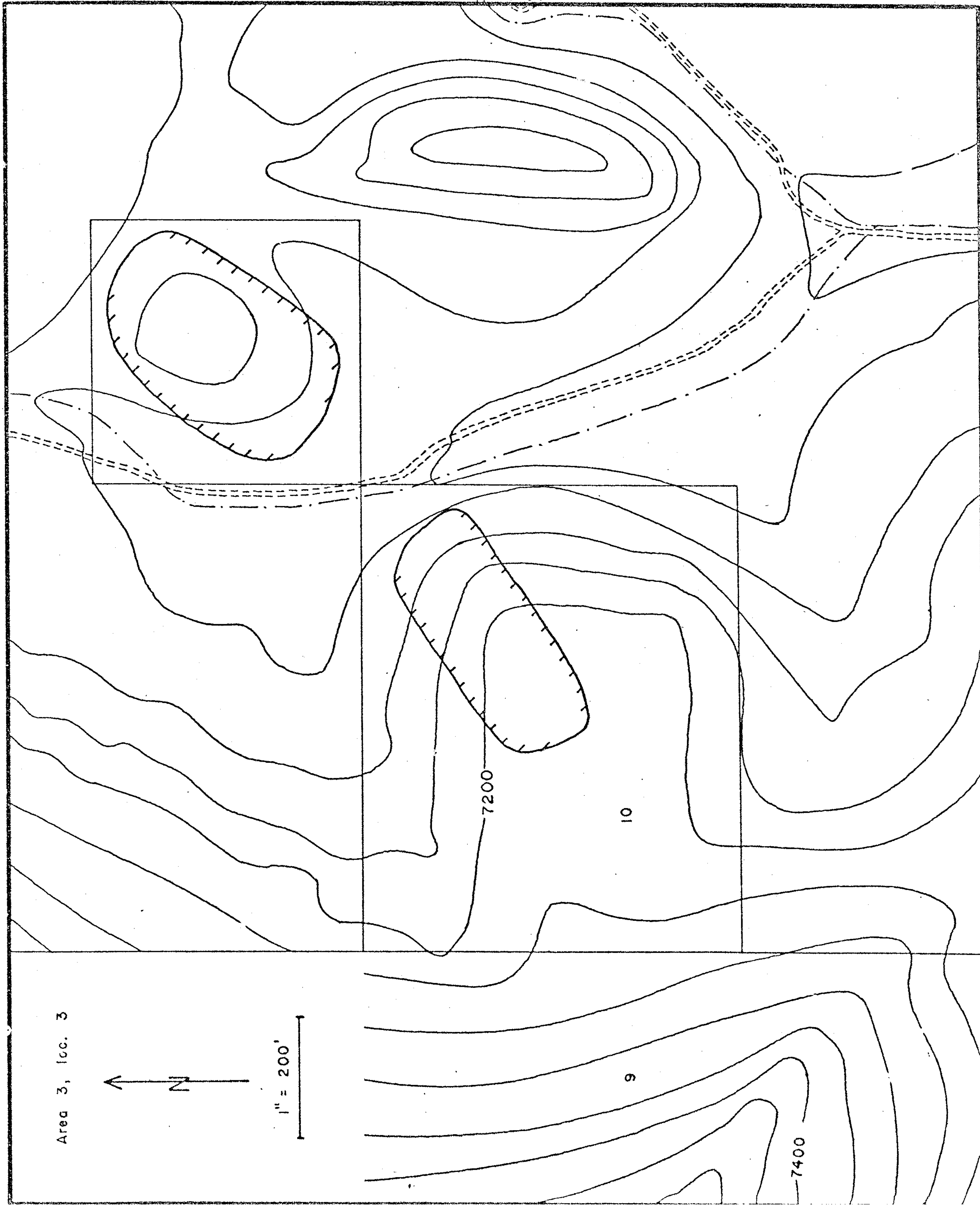


Photo #12. Basalt on the east side of the road near an old pumice strip mine in area #3, locality #3.

Figure 9.



Campground along Forest Route 271 and 500 feet (152.4 m) north on the old strip mine trail. This appears to be a unit of basalt tilted to vertical due to nearby faulting (Photo #12 & #13). There is approximately 50 feet (15.2 m) by 100 feet (30.5 m) by 200 feet (60.9 m) of exposed basalt on each side of the road. The vegetation is dense consisting of Ponderosa Pine and scrub oak. The tonnage from both sides of the road is estimated to be at least 92,000 tons with very small amounts of overburden.

Locality #4 is accessible by traveling 3.1 miles northeast along Forest Route 271 from the Paliza Campground junction (Fig. 10). A left turn is then made onto a jeep trail which is followed 1.0 mile north (SW¼, SE¼, sec. 35, T18N, R3E). On the north side of the road is a unit of basalt approximately 80 feet (24.4 m) thick, 150 feet (45.7 m) wide and 500 feet (152.4 m) long (Photo #14). The estimated tonnage exceeds 270,000 tons of crushed basalt. This basalt deposit lies near a major structure, therefore, it is quite broken near the top. The vegetation is dense consisting of rather mature Ponderosa Pine.

Area #5

Area #5, consisting of approximately 25 square miles, is north of area #2 and east of San Pedro Parks Wilderness (see Plate IV). Available access includes Forest Route 93, 103, 316, 385, 453, 457, and 461. Pennsylvanian limestone is again the most likely source of aggregate. This limestone crops out only in the southern portion of the area.

In location #1 a thin- to medium-bedded fossiliferous limestone forms a sparsely vegetated plateau-like feature (Photo #15). It is slightly north of the intersection between the Rito Cafe and the Rio Peñas Negras (SE¼, NE¼, sec. 27, T21N, R2E)(Fig. 11). The limestone unit is 10 feet (3.05 m) to 15 feet (4.6 m) thick, 500 feet (152.4 m) long and 500 feet wide. Small shale

Photo #13. Basalt on the west side of the road near an old pumice strip mine in area #3, locality #3.

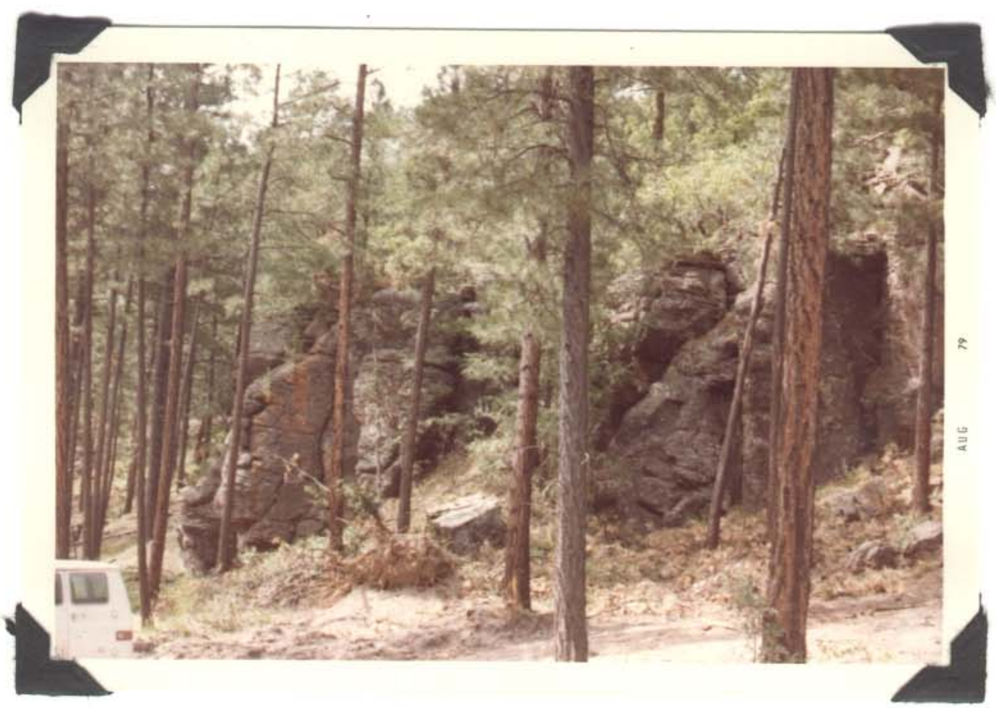


Photo #14. Basalt in Paliza Canyon on an old jeep trail in area #3, locality #4.

Figure 10.

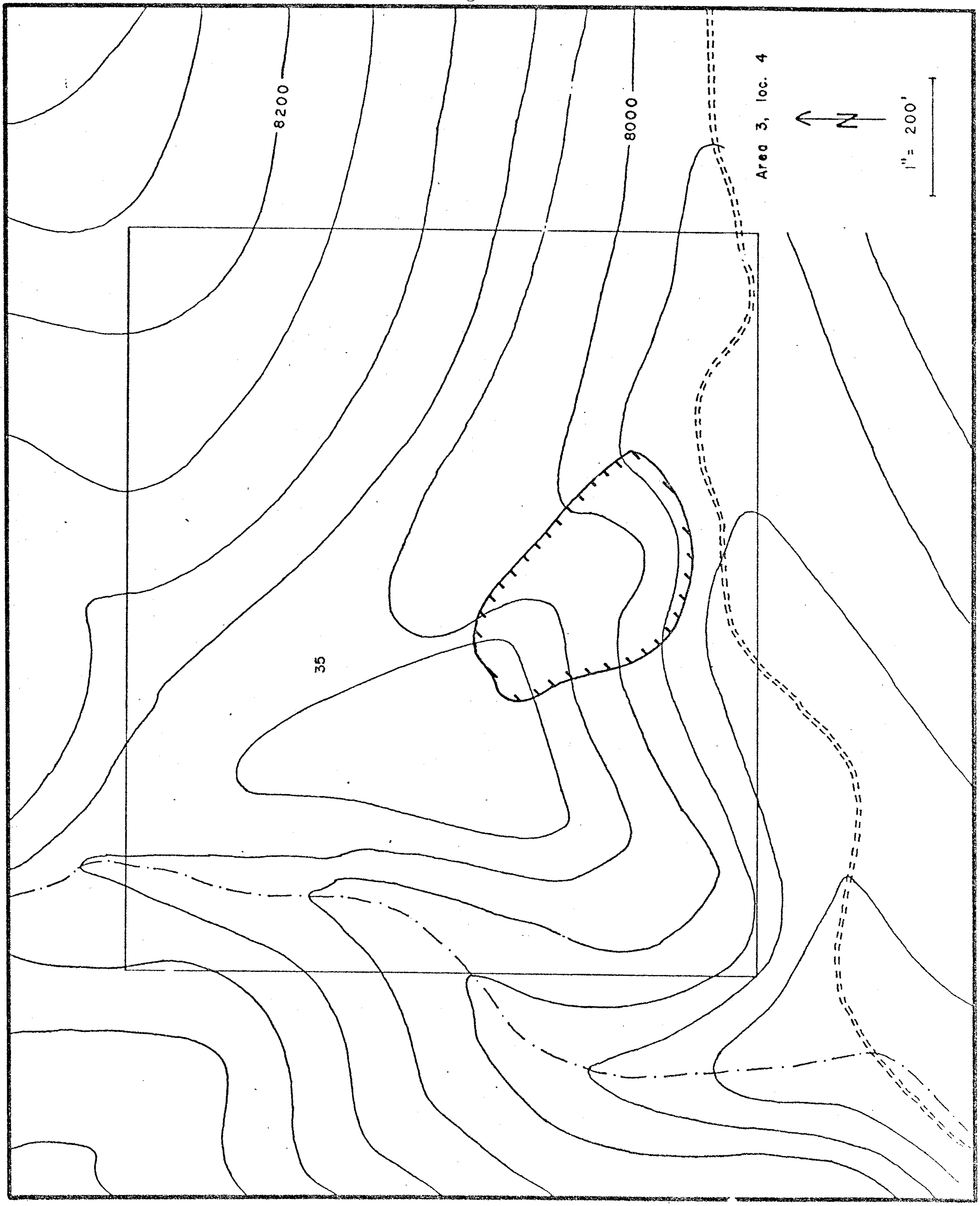


Photo #15. Madera Limestone capping a plateau north of the intersection of Rito Peñas Negras and Rito Cafe in area #5, locality #1.

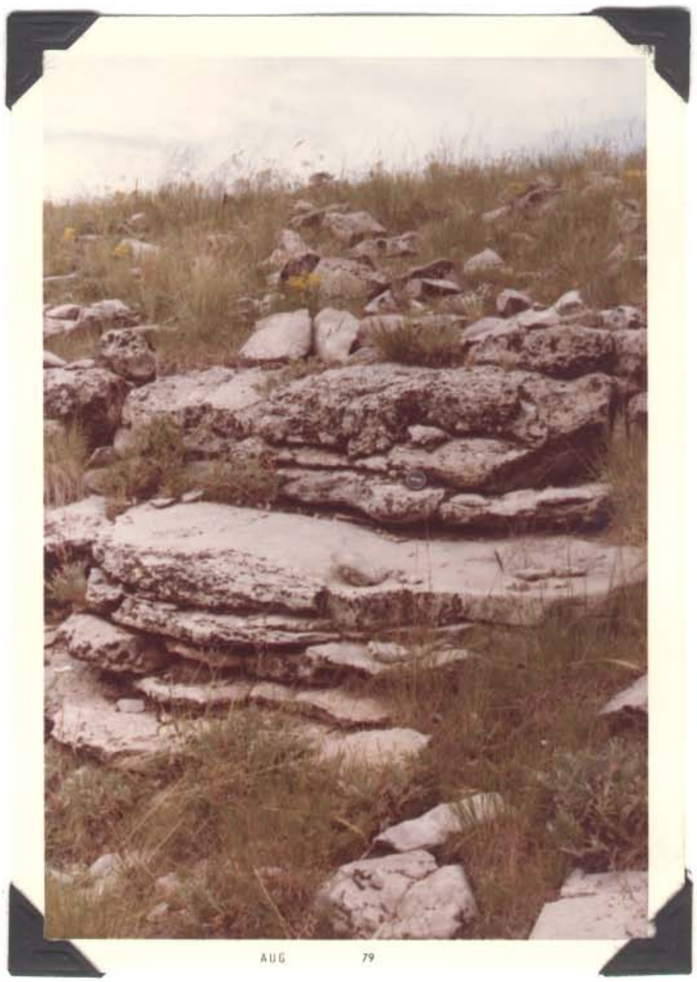
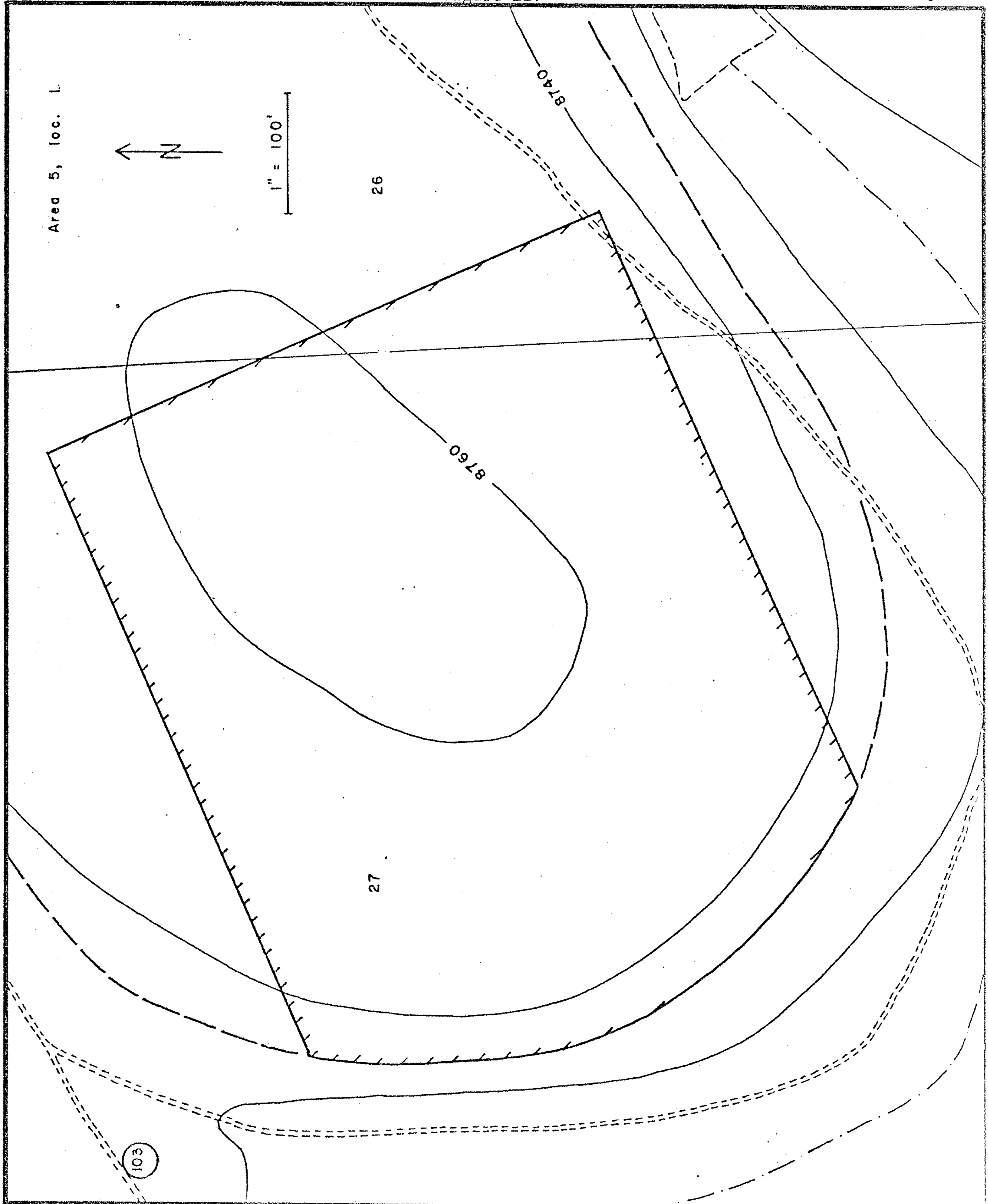


Photo #16. Madera Limestone caprock referred to in photo #15 (area #5, locality #1).

Figure 11.



seams are present between beds but do not exceed more than 10% of the total thickness (Photo #16). The overburden should not exceed more than 5 feet (1.5 m) at its thickest point. Trees are nearly absent from this area leaving grass as the only vegetation. The estimated tonnage is 178,470 tons of crushed limestone.

Locality #2 is northeast of Rito Cafe and south of the Nacimiento Stock Drive (E½, SW¼ and W½, SE¼, sec. 22, T21N, R2E)(Fig. 12). This unit is very poorly exposed but appears to be 8 feet (2.4 m) thick, 1000 feet (305 m) long and 1000 feet wide. Overburden may be quite thick and supports a dense growth of pine and underbrush (Photo #17 & #18). Much of this locality may be privately owned and used for summer range. Access exists through the private land in the area on what are assumed to be private roads. Tonnage for the forest land only and with possibly less than 10 feet (3.05 m) of overburden was calculated as 51,000 tons.

Area #6

Area #6 includes about 30 square miles and lies south of Fenton Lake and La Cueva, New Mexico. Access is obtained on Forest Routes 376, 604, 606, 607, 608, 609, 611 and 656. The area consists of mesa-like ridges and deep stream canyons draining southwest into the Rio de las Vacas.

This area is very disappointing since it contains no rock type suitable for aggregate material. The primary rock occurring in this area is the Bandelier Tuff. Although the tuff is densely welded in certain areas, it is our opinion that it is much too soft to make reliable aggregate. There are small areas where the Paliza Canyon Formation outcrops, but these occur at the base of steep canyon walls and are overlain by hundreds of feet of Bandelier Tuff.

Figure 12.

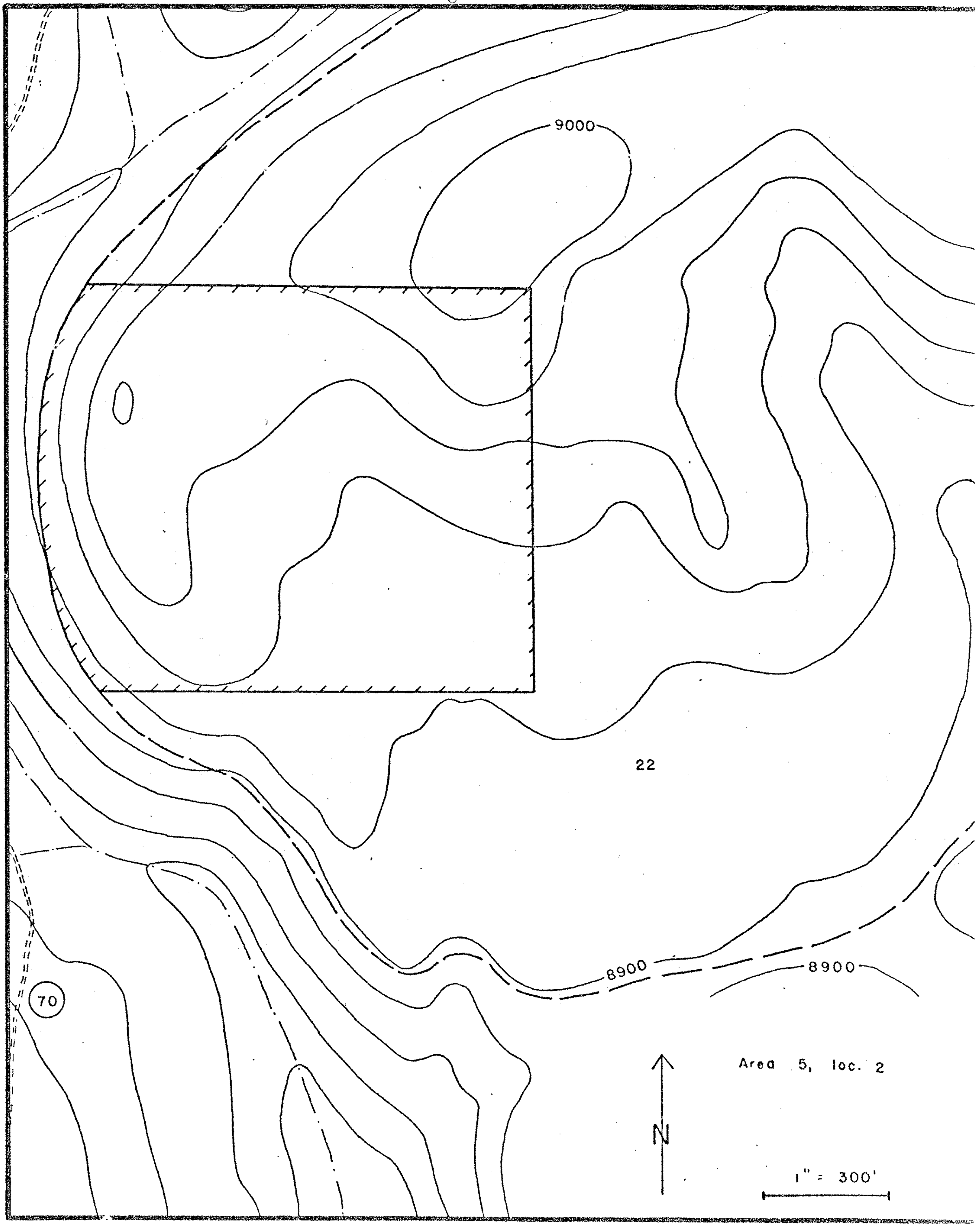


Photo #17. Ridge in area #5, locality #2, which is capped by Madera Limestone.

Photo #18. Vegetative cover on top of ridge in photo #17 (area #5, locality #2).

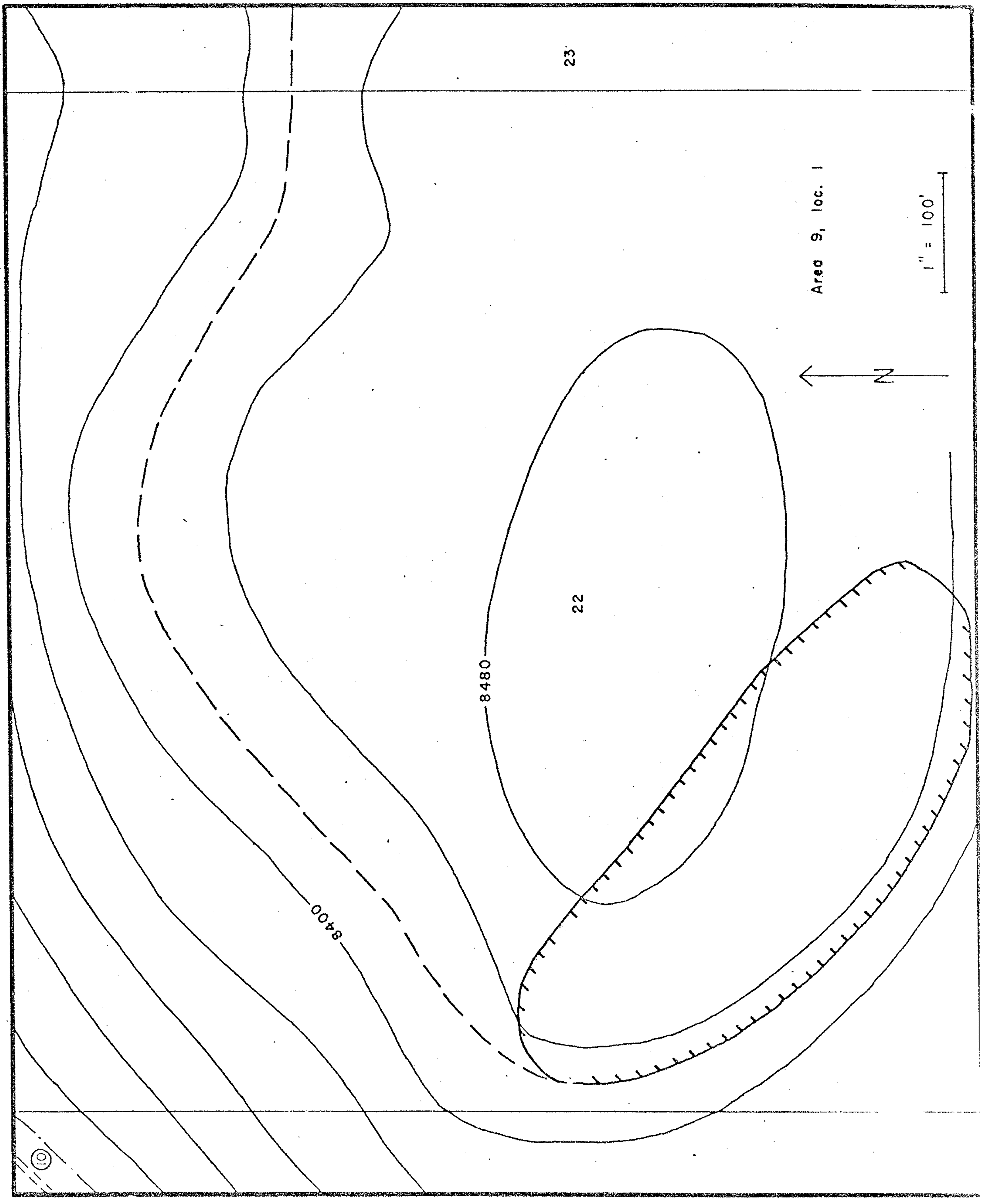
Area #9

Area #9 consists of approximately 21 square miles of National Forest land, south of, and including Vallecitos de las Indios (see Plate V). Access is obtained on Forest Routes 10, 135, 136, 269, 270, and 490. Unfortunately, time permitted only two days to be spent on general reconnaissance of the area.

Locality #1 is east of Dead Horse Spring (NE¼, SE¼, sec. 21, T18N, R3E), on Forest Route 10 (Fig. 13). This area consists of a highly vesicular porphyritic dacite capping a small ridge between two intersecting streams (Photo #19 & #20). This unit is part of the Paliza Canyon Formation and appears to be about 30 feet (9.1 m) thick. Overburden is variable but tends to increase as you move away from the edge of the ridge. Much of the overburden appears to be pumice which may be float from the Bandelier Tuff. Lateral dimensions are 100 feet (30.5 m) by 150 feet (45.7 m) with less than 5 feet (1.5 m) of overburden. Tonnage estimates indicate that there may be as much as 20,830 tons of crushed basalt in this deposit.

Location #2 occurs along Forest Route 270, 2.75 miles from its intersection with Forest Route 10 (Fig. 14). It is easily seen from the road and appears crumbly due to shearing caused by nearby structure (Photo #21). It is a black highly vesicular flow basalt which appears to be at least 20 feet (6.1 m) thick. It is a very local unit and may have greater than 5 feet (1.5 m) of overburden in most places. It occurs on both sides of the road and is covered with a dense growth of pine, aspen and scrub oak. The tonnage may be as high as 15,000 tons on both sides of the road but 75% of this involves overburden between 5 feet (1.5 m) and 10 feet (3.05 m) thick.

Figure 13.



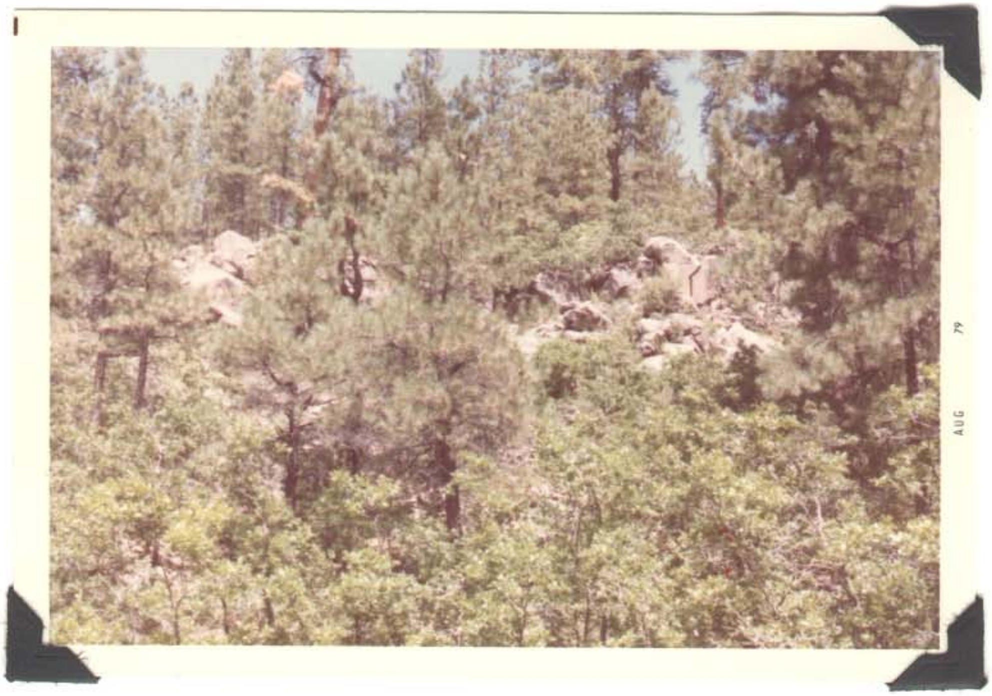


Photo #19. Ridge capped with dacite east of Dead Horse Spring in area #9, locality #1.

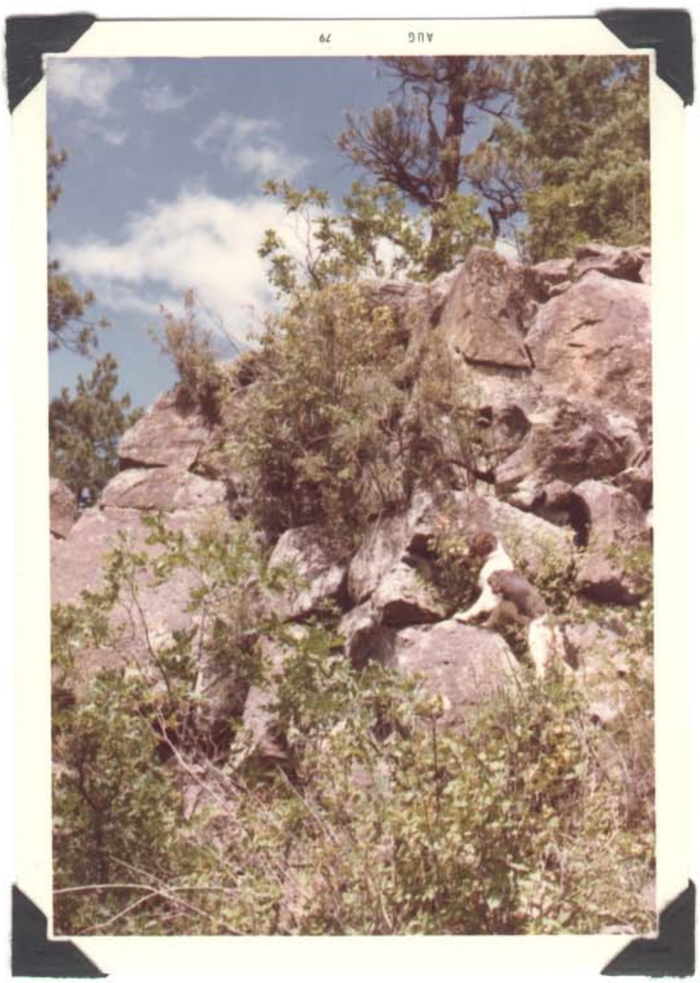


Photo #20. Blocky outcrop of dacite capping the ridge seen in photo #19 (area #9, locality #1).

Figure 14.

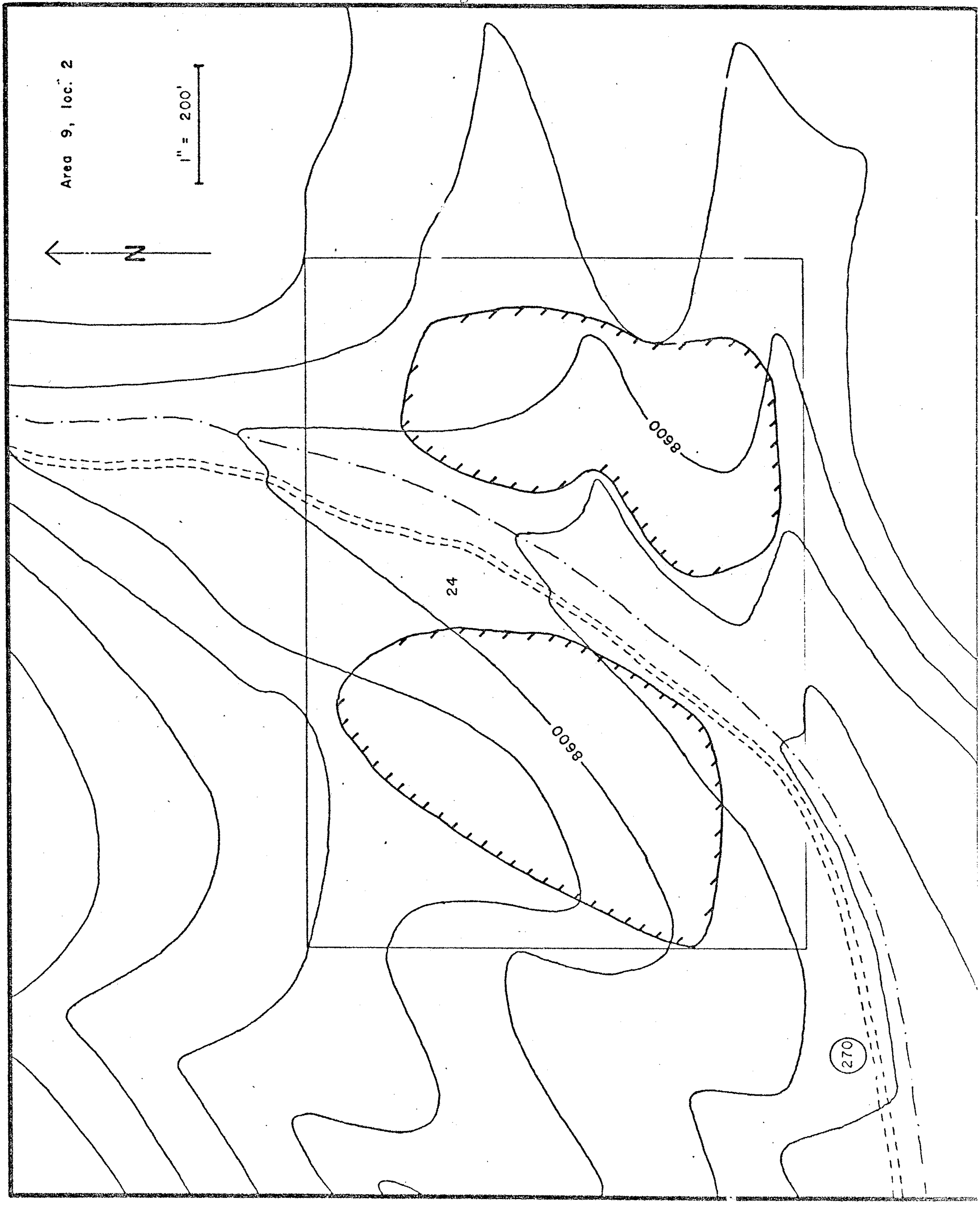


Photo #21. Sheared basalt on Forest Route 270. This appears more blocky in the upper center of the photograph (area #9, locality #2).

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