PLUVIAL HISTORY OF PANAMINT VALLEY, CALIFORNIA

A GUIDEBOOK FOR THE FRIENDS OF THE PLEISTOCENE, PACIFIC CELL

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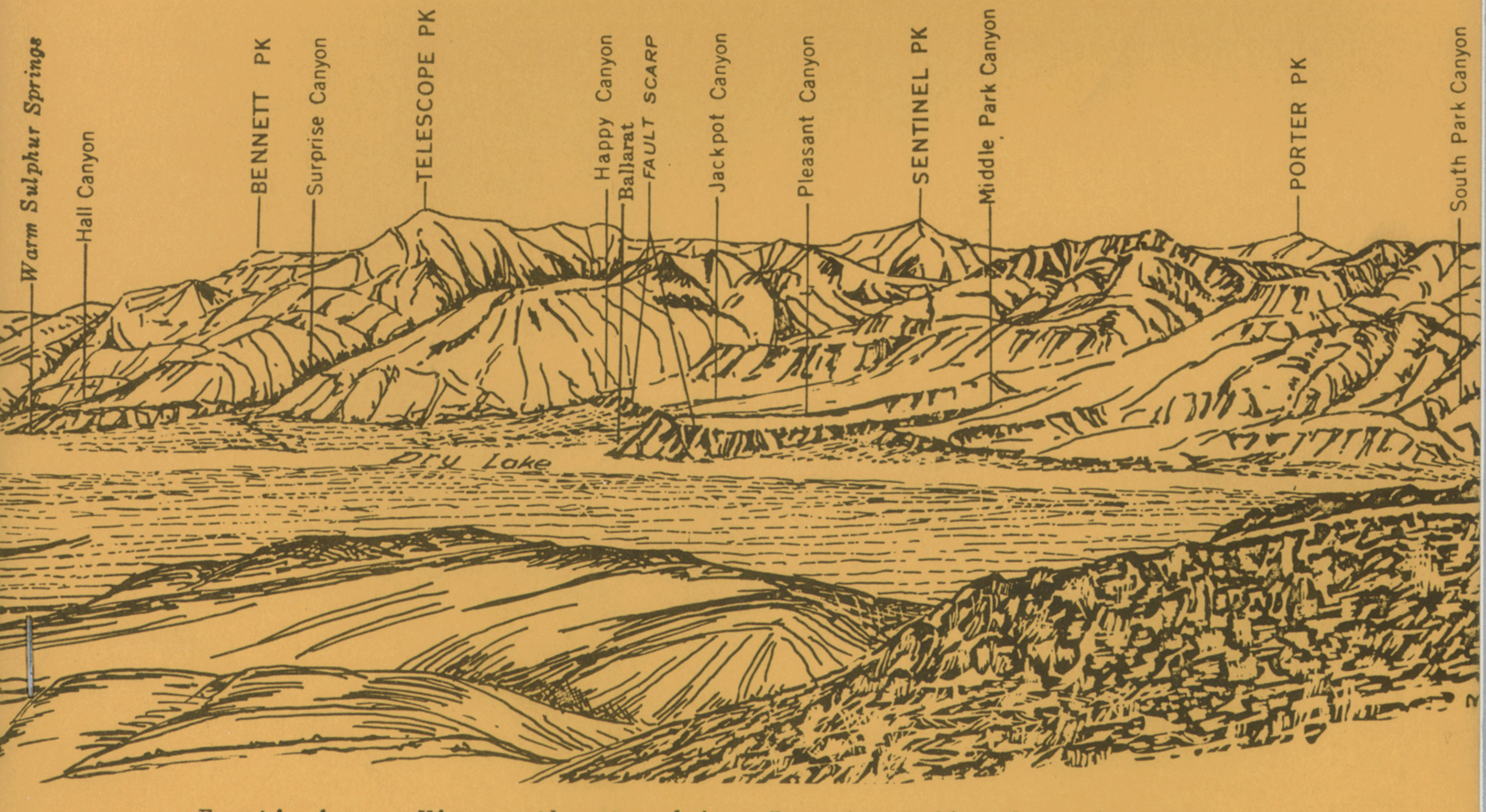

Frontispiece. View northeastward into Panamint Valley from Slate Range crossing. (Sketch by Esther McDermott)

ROAD LOG

Start at turnoff to Valley Wells, 2.5 miles north of Inyo-San Bernardino county line at north end of Trona. Be prepared--there are no facilities or supplies now available anywhere in Panamint Valley.

Cumulative Mileage	Net Mileage	
8.9	8.9	Summit of pass into Panamint Valley. This spectacular view is labelled on the frontispiece. There is very little parking space here, so don't stop and don't slow down too much because heavy trucks frequent this route. The road ahead is steep, narrow and winding, so drivers won't see much until they get down the hill.
10.5	1.6	At three o'clock about two miles distant, a large body of light-toned sand and gravel marks the highest stand of pluvial Lake Panamint. Its elevation is 2000 feet.
12.35	3.45	Paved Nadeau Road ("Onyx Mine") on left. Stay on main road.
15.5	3.15	STOP 1 (0800). Assemble vehicles on broad gravelly surface to right of highway. Peruse high shorelines above Ballarat while group assembles (frontispiece, figs. 1,2).
16.0	0.5	Turn right onto dirt road to Ballarat across south Panamint playa. Repairs to the road embankment mark places where water flooding the playa breached it during the unusually wet winter of 1978.
19.5	3.5	Ballarat (Ghost town). Park ordinary vehicles here and board high-center vehicles for ride up Pleasant Canyon to trailhead (about 1.1-1.5 mi.). THIS IS A 6-HOUR WALKING STOP, SO BRING CANTEEN, LUNCH AND EVERYTHING ELSE YOU NEED. WE'LL NOT RETURN TO PARKED CARS UNTIL AFTER STOP 3.
		STOP 2. (0830). Chronology of pluvial Lake Panamint revealed in stratigraphy of nearshore deposits on the north side of Pleasant Canyon. Figure 14 shows route.
		Retrace route to Ballarat, then turn south on dirt road. Stay in high-center vehicles to save time (and dust).
22.9	3.4	Steeply-dipping foreset beds are clearly visible in the gravel atop the 100-foot scarp to left of road (unless obscured by dust from vehicles ahead of you). This gravel lies along the shoreline of the youngest major lake stand to occupy the valley, more of whose features will be seen at Stop 3.
23.5	0.6	STOP 3 (1415). Park on both sides of road and ascend slope to southeast to highest of the series of low shorelines. Figure 15 shows route.

Cumulative Mileage	Net Mileage	
27.5	4.0	Ballarat, once again. Retrieve parked cars and turn left onto dirt road to highway. If you prefer to stay close to the range front (and eat dust), you can proceed straight north on dirt road to intersect highway farther along (11.2 miles).
31.1	3.6	Turn right onto main highway.
40.2	9.1	Wildrose Junction. Turn gently right (stay on main paved road). The dirt road at sharp right leads back to Ballarat. If you're in a hurry to get to Death Valley and want to skip Stop 4, the paved road to the left leads to California highway 190 (14.4 miles), onto which you can turn right to get to Death Valley (Emigrant Junction, 18.2 mi.).
43.1	2.9	STOP 4 (1600). Park here along road as close together as possible--there may be insufficient room for all cars. If time is long, we plan to climb over hill to left of road to view deposits and faulting of the high paired shorelines. If time is short, we plan to climb hill to right of road to view high paired shorelines. The routes are shown on fig. 16.
44.45	1.35	You are now entering the Wildrose graben, having followed the road up an incised channel beheaded by fault movement along this west wall of the graben.
49.65	5.2	The road to the right leads to Wildrose ranger station & campground. Bear left onto main road to Death Valley--this is a slow, steep, winding road. No supplies are now available at Wildrose.
70.7	21.0	Emigrant Junction. Turn right onto Calif. highway 190.
79.8	9.1	Stove Pipe Wells. Gasoline may be available here.
86.8	7.0	Sand Dune Junction. Bear right on Calif. 190.
93.2	6.4	Beatty Junction. Continue ahead on Calif. 190.
104.3	11.1	Turn left onto paved road to Texas Spring Campground. Our reservation for Group Area K is listed as being for the University of Minnesota. There is an overflow campground (parking lot) at Furnace Creek or you can overflow into the desert outside the National Monument (about 15 miles).

INTRODUCTION

The Owens-Manly Pluvial Lake System

Large, interconnected pluvial-lake systems filled many of the closed basins between the Sierra Nevada and the Wasatch Range during some parts of Pleistocene time. Although the lake system sumping in Death Valley never coalesced into a single lake, its drainage area was exceeded only by that tributary to lakes Lahontan and Bonneville. The historic remnants of this lake system are Owens Lake (now dry from water diversion) and Mono Lake.

During Tahoe time, water overflowing from Lake Russell (ancestral Mono Lake, Putnam, 1949, p. 1295-6) is judged to have reached Death Valley as Owens, China, Searles and Panamint lakes filled in succession and spilled into the next basin in line: Lake Panamint overflowed into Lake Manly (Blackwelder, 1933; Hooke, 1972) in Death Valley. Lake Manly also received discharge from the Amargosa River, draining southwestern Nevada, and from the Mojave River, including lakes Manix and Mojave, draining the San Bernardino Mountains south of the Mojave Desert.

The pluvial lakes in Searles, Panamint and Death valleys were first shown on Russell's (1885, pl. 1) map of "Quaternary Lakes of the Great Basin," but no mention of them was made in the text. Bailey (1902, p. 12, 16-17) postulated that all these lakes were desiccational remnants of an enormous Quaternary lake, covering most of the Mojave Desert. Campbell (1902, p. 20) noted the high shorelines of Lake Panamint near Ballarat but did not recognize that they stood at an elevation near that of the basin's lip. Lee (1906, p. 7) cited the first evidence for Owens Lake's having formerly overflowed southward into Indian Wells Valley. Free (1914, p. 39-41) likewise recognized that Searles Lake had been fed by overflow of Owens Lake, but thought that Lake Panamint had been a small lake fed mainly by local runoff, which never approached overflow levels and only briefly received discharge from Searles Lake.

In what is still the most detailed study of many aspects of this lake system, H. S. Gale (1915, p. 315-7) proposed that Lake Panamint had overflowed into Death Valley via Wingate Pass (fig. 1), whose elevation coincided with that of shorelines farther north. Although Gale did not visit Wingate Pass, Thompson (1929, p. 186-7) accepted the likelihood of overflow through the pass after finding rounded gravel both there and downstream in Wingate Wash. In the first thorough description of Lake Manly in Death Valley, Blackwelder (1933, p. 468-9) agreed that it was fed by overflow from Lake Panamint during Tahoe time, but thought that its major tributary had been the Amargosa River. In later papers, Blackwelder (1941, 1954) persisted in this belief because he found evidence for overflow of Searles Lake only during Tahoe time. During Tioga time, he thought that the depth of Lake Panamint was only 200 feet (compared with 950 feet during Tahoe time, when it overflowed) and that the depth of Lake Manly was 400 feet (compared with 600 feet during Tahoe time). However, recent work by G. I. Smith (1968, p. 307) has shown that Searles Lake did indeed overflow during Tioga time. From the earlier studies of the Searles Lake cores and their radiocarbon ages, as reported by Flint and Gale (1958) and Stuiver (1964), and supplemented by his own exhaustive work on the exposed lake deposits, G. I. Smith (1976) has constructed a curve of the fluctuations of the level of Searles Lake for the last 130,000 years.

Lake Panamint

Lake Panamint was a deep lake in a flat-bottomed basin with gentle to steep sides. At its overflow level, its depth exceeded 950 feet, its area was about 300 square miles and its volume about 92 million acre feet. The lake basin is divided into north and south basins by a drainage divide at about 1715 feet elevation. This contour encloses an area about three times greater in the south basin than in the north and a volume about 12 times greater.

Lake Panamint could have had long-enduring stands at any of three stable elevations: 1) low stands, elevation $<$1165 feet in the south basin and 1540-1560 feet in the north basin; 2) Intermediate stands in the south basin, elevation about 1715 feet; and 3) high stands, elevation 1977$\pm$1 feet.[1] The elevation of the low stands depended on how large a surface of evaporation could be sustained primarily by local runoff. Evidence for low stands is seen in both south and north basins. The elevation of the intermediate stands was controlled by overflow of Sierra Nevada water from the south basin into the north basin through the 1715-foot divide between them. The stability of this lake level depended on the ability of evaporation to consume all the water which overflowed into the north basin. Because of the delicacy of this required balance between inflow and evaporation, this level was probably not continuously occupied but, rather, intermittently occupied by both rising and falling lakes. The evidence for shorelines attributable to this level is largely equivocal. The elevation of the high stands was controlled by overflow of runoff into Death Valley (Lake Manly) through Wingate Pass, elev. 1977$\pm$1 feet. Shorelines traceable to this level are the most prominent ones seen in Panamint Valley today.

The elevation of the outlet lip of Lake Panamint through Wingate Pass seems to have been raised abruptly during pluvial times because the bedrock lip was buried beneath a mudflow. Evidence for overflow across the bedrock lip now buried 47$\pm$16 feet beneath Wingate Pass is provided by the ubiquity of paired high shorelines throughout Panamint Valley. For almost all paired shorelines, the fainter, lower shoreline lies less than 47 feet below the prominent, higher shoreline in uplifted areas but lies more than 47 feet below the prominent, higher shoreline in downwarped areas. The amount of tectonic deformation of the lower shoreline is greater (1.26x) than the amount of deformation of the higher shoreline (fig. 20). This suggests that the age of the lower shoreline is about 1.26 times greater than the age of the higher shoreline.

STRATIGRAPHY OF NEARSHORE DEPOSITS AT PLEASANT CANYON

Introduction

The uplifted shorelines and associated lake deposits athwart the mouth

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[1] Early high lake stands were probably stabilized at the level (1930 $\pm$ 15 feet) of the bedrock lip beneath Wingate Pass, whose level seems to have been raised to its present elevation by a mudflow which buried the bedrock lip during the early history of the high lake stand which cut the most prominent shoreline.

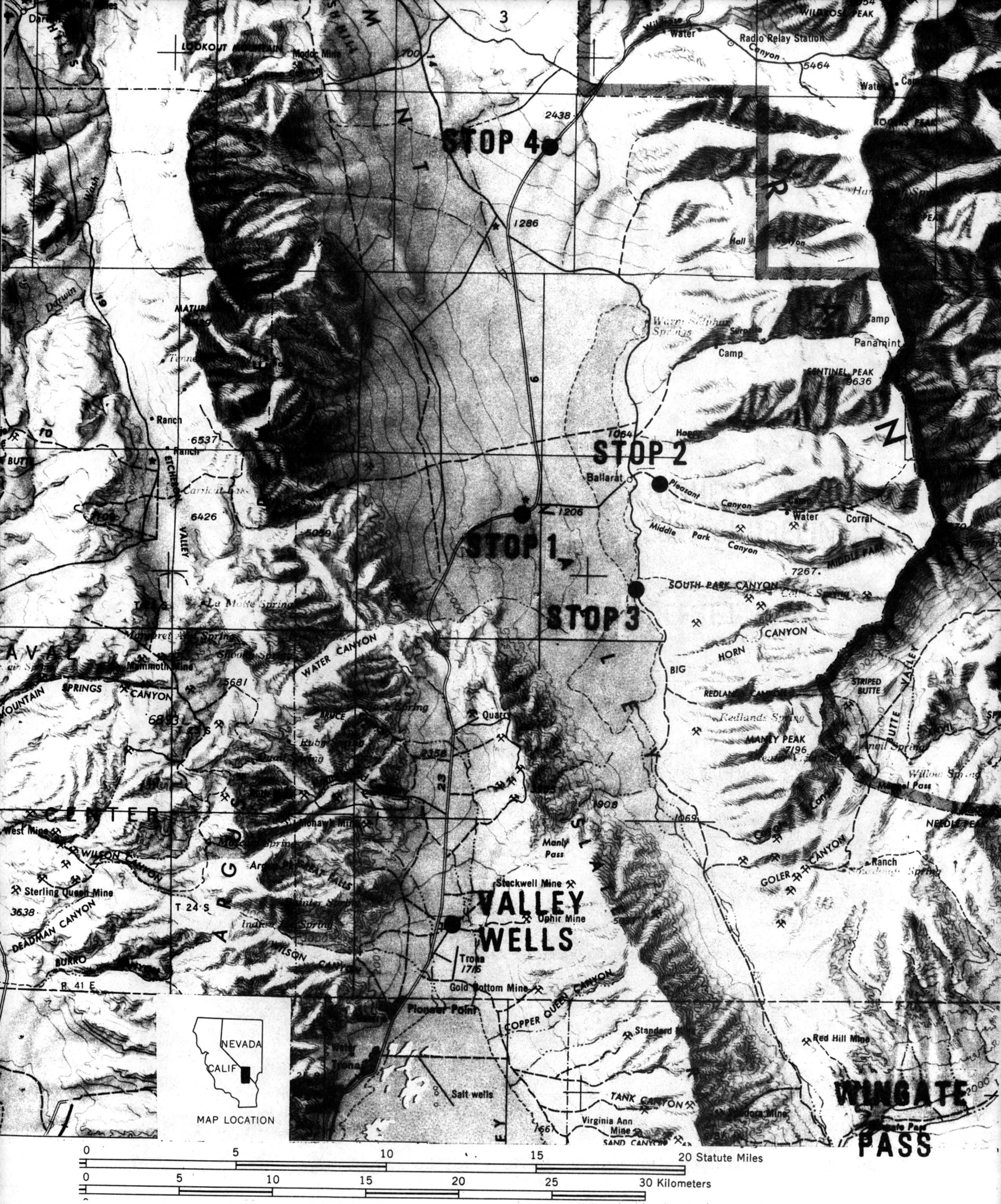

Figure 1. Index map of Panamint Valley.

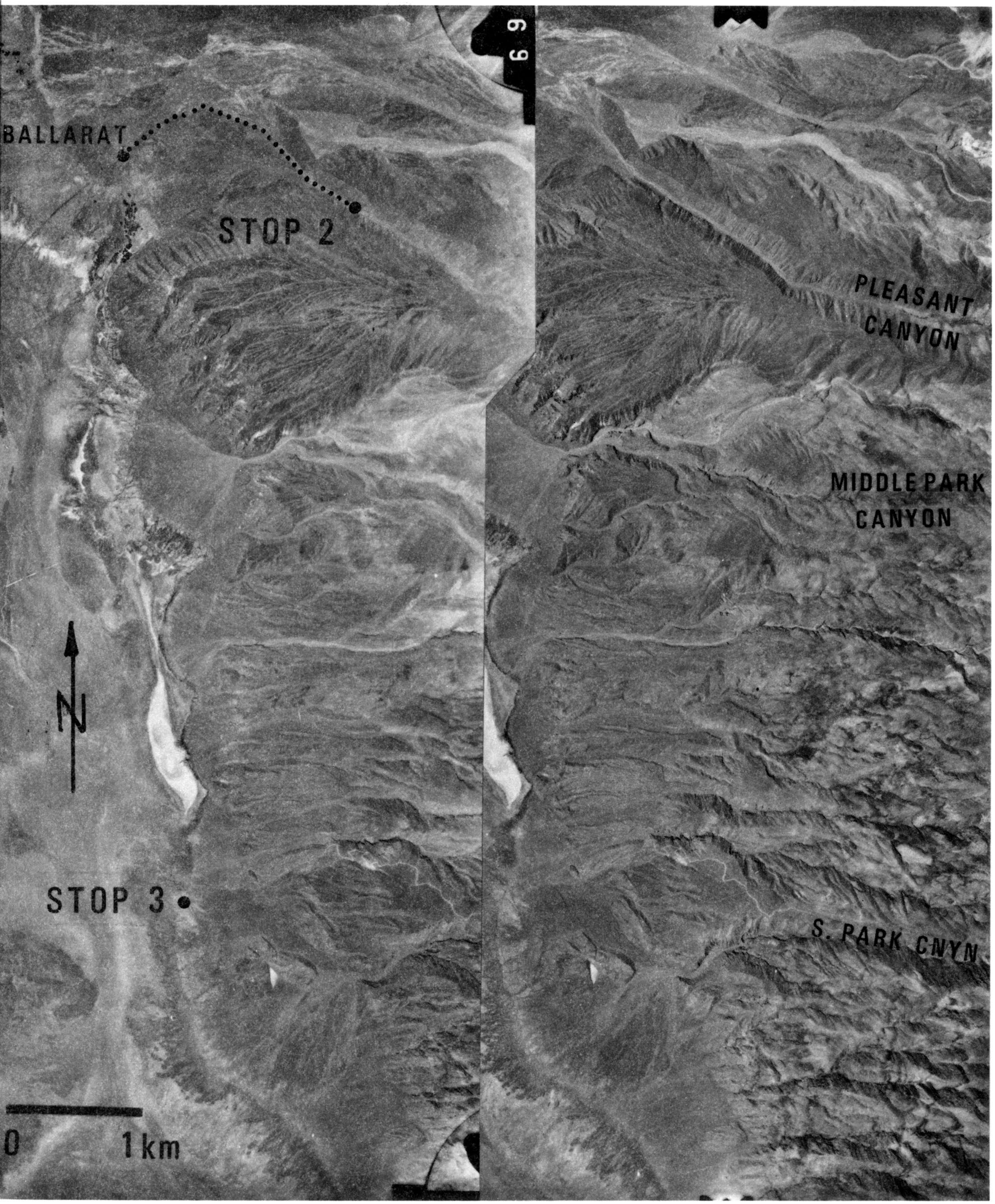

Figure 2 Stereogram of range front between Pleasant and South Park canyons. (GS-VEDP 1-155,156; 7-10-76)

of Pleasant Canyon in the Panamint Range east of Ballarat provide a more complete and detailed record of the history of Lake Panamint than is found anywhere else in the valley (fig. 2). This record, presented schematically on Figure 3 forms the basis for the summary discussion of Panamint Valley's pluvial chronology.

The north side of lowermost Pleasant Canyon is the type locality for the lake stages and substages described in this section (fig. 5). Progressively older lake deposits are stratigraphically associated with shorelines at progressively higher elevations. All shorelines with present elevations from 2040 to 2410 feet were probably formed by lake stands stabilized by overflow through Wingate Pass (present elevation 1977±1 feet; elevation of buried bedrock lip 1930±15 feet). Three intermediate-level shorelines with present elevation from 1890 to 2025 feet were probably formed by lake stands stabilized by overflow from Panamine Valley's south basin into its north basin (present pass elevation 1715±5 feet). Differential vertical movement is suggested by the difference in elevation of these shoreline levels and their overflow sill levels.

If a modern, intermediate-level shoreline formed in Panamint Valley, its level (1715 feet) would be 262 feet below the level of a modern high shoreline formed with respect to the level of Wingate Pass (1977 feet). If both shorelines were uplifted, the vertical separation between them would be preserved. By analogy, an ancient, intermediate-level shoreline should lie about 262 feet below an ancient, high shoreline of the same age formed with respect to the modern elevation of Wingate Pass, regardless of how much the two shorelines have since been uplifted. Similarly, an older ancient, intermediate-level shoreline whould lie about 215 feet below an ancient high shoreline which formed with respect to the bedrock lip buried beneath Wingate Pass (elevation 1930±15 feet).

Distinctive shorelines were probably cut only at lake levels stabilized by overflow through Wingate Pass or (at lower level) by overflow across the sill into north Panamint Valley. Lake stands at other levels were not stabilized by overflow and thus fluctuated too sharply and were too ephemeral to leave identifiable records.

The shorelines at Pleasant Canyon are situated near the north end of a band of high shorelines which extends along the foot of the Panamint Range from South Park Canyon five miles north almost to Happy Canyon (fig. 1). The topographic form of these shorelines is distinct and they can usually be clearly discerned from the west side of Panamint Valley. They were recognized by Campbell (1902, p. 20), one of the earliest workers in the area, and have attracted comment from others (Maxson, 1950, pl. 10; Wright and Troxel, 1954, p. 23; Johnson, 1957, p. 412; Carranza, 1965, p. 58; Shelton, 1966, p. 357). Hoyt Gale's (1915, p. 314-6) pioneering study has been the most thorough previously-published investigation of these shorelines.

Nomenclature

The most prominent shoreline at Pleasant Canyon was formed during a high lake stand herein named "Gale Stage" in honor of Hoyt Gale. This shoreline can be traced almost continuously from South Park Canyon to Pleasant Canyon. Its beaches are broader, its beach cliffs higher, and the bulk of associated lacustrine gravel deposits far greater than corresponding features associated with any other stage of Lake Panamint. Gale-Stage beaches

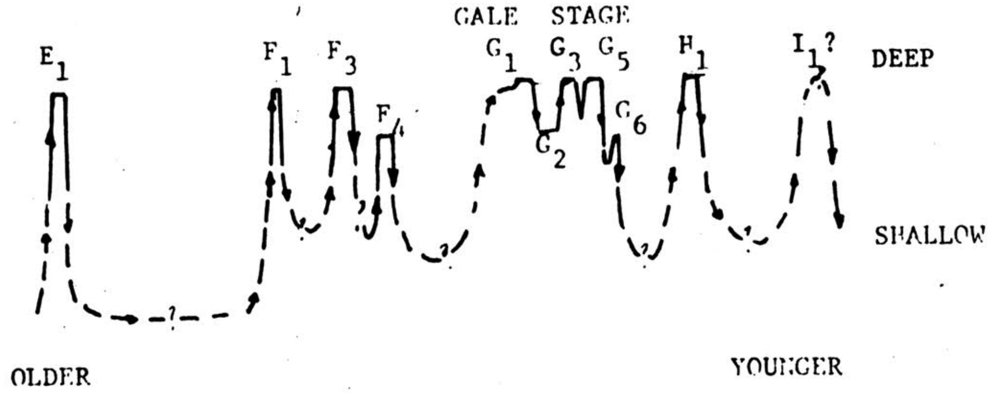

Figure 2. Diagrammatic sketch of the fluctuations in the level of Lake Panamint inferred from shoreline and stratigraphic relationships at Pleasant Canyon.

Table 1. High and intermediate stands of Lake Panamint at Pleasant Canyon.

High Stands Stage	Elevation	Intermediate Stands Stage	Elevation	C^{14} Age
I_1?	2040±40 ft. ?			
H_1	2127±10			>31,150±1400 BP >34,300±1000 BP
Gale Stage		Gale Stage		
		G_6?	1890±25	
G_5, G_3, G_1	2177±10	G_2	>1920±20	>33,700±500 BP
		F_4	2025±15 ?	
F_3	2265±10			
F_1	2298±10			
E_1	2410±10			

↓ Oldest

Figure 4a. Aerial view looking southeast toward lake shores and deposits north of Pleasant Canyon.

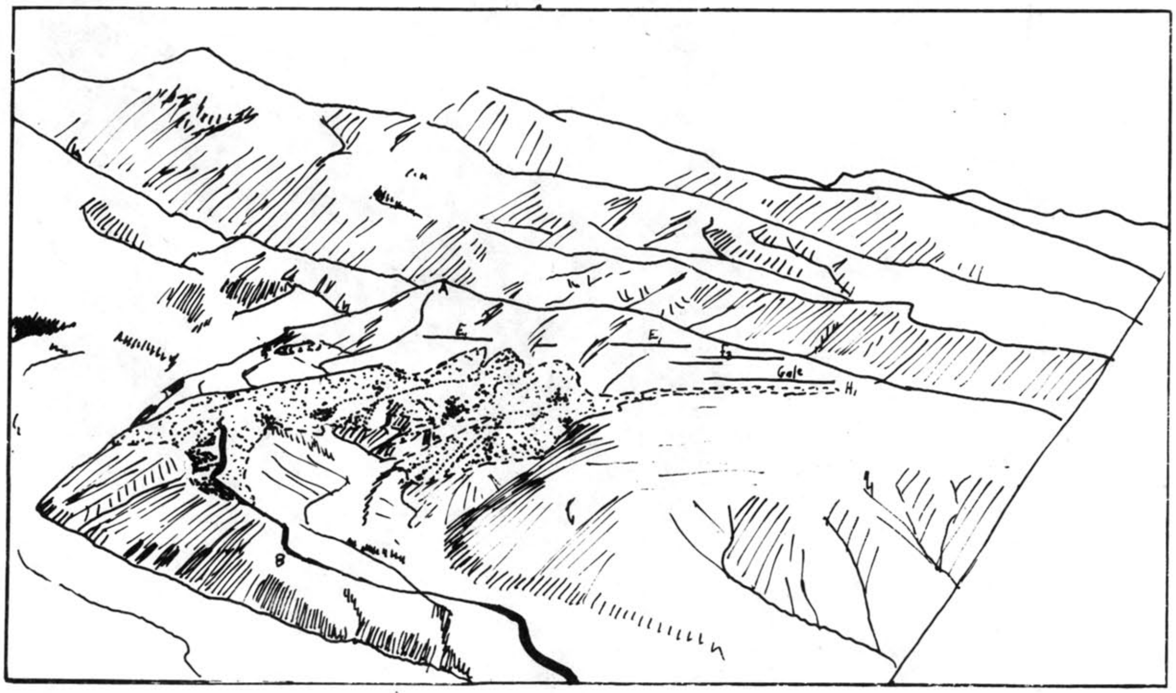

Fig. 4b. Sketch of fig. 4a. Lake deposits are stippled.

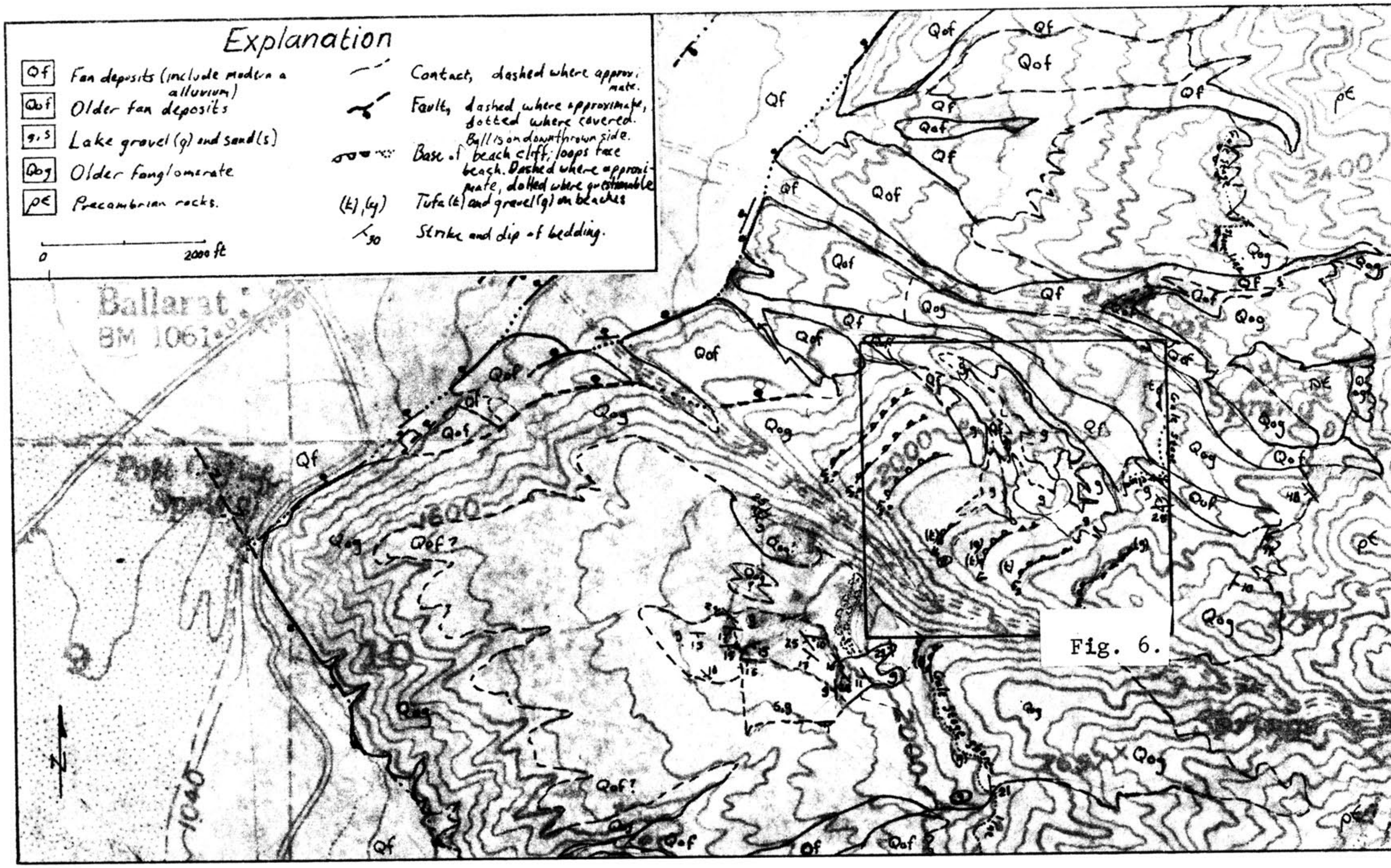

Figure 5. Geological map of the mouth of Pleasant Canyon.

are abundantly littered with tufa, generally rare on beaches attributed to other stages. Prominent high shoreline remnants seen elsewhere in Panamint Valley were probably formed during Gale-Stage time.

All lake stages recognized are alphabetically designated E, F, G, H, I from oldest to youngest, with "G" being Gale Stage. All substages of Lake Panamint thought to have been stabilized by overflow through Wingate Pass are designated by odd subscripts, and non-overflow substages are designated by even subscripts regardless of whether or not the lake's level may have been stabilized at the spillway elevation into north Panamint Valley. The recognized stages and substages of Lake Panamint are tabulated on Table 1 and will be described from oldest (E_1) to youngest (I_1).

Lacustrine Succession and History of Dissection

The sequence, amount of deposition and degree of dissection of lake-shore sediments of pre-Gale levels is poorly known compared to that of Gale and later levels. Contact relationships between E_1, F_1, and F_3 deposits are poorly exposed, but the basal G_1 contact on fanglomerate and F-stage gravel is extensively exposed in modern gullies, as is the internal stratigraphy of Gale-Stage deposits. A prominent bottomset G_1 sand and an overlying deltaic(?) gravel filled a system of northwest-draining gullies which had been incised 50 to 100 feet into fanglomerate and older lake deposits (F and E?). The pattern of these gullies resembled that of the modern drainage, but modern gullies are about 10 feet deeper. During the following low stand of the Gale-Stage lake (G_2), the G_1 deposits were dissected by a shallow set of gullies which drained northeast, parallel to the shoreline, and emptied into the large, northwest-draining wash which now runs along the northeast margin of the entire Pleasant Canyon deposit of lake sediments (fig. 6). These gullies were filled with gravel during the lake's next overflow stand (G_3). The G_3 deposits were not discernibly dissected prior to deposition of G_5 gravels, but slight dissection of G_5 gravels by broad, shallow northeast-draining gullies preceded deposition of H_1 beds. This succession of deposits is mapped on Figure 6 and shown in cross section on Figure 7.

Deposits Older than Gale Stage

All pre-Gale high stands of Lake Panamint were probably stabilized by overflow across the bedrock lip (1930±15 feet) now buried beneath Wingate Pass.

<u>E_1 (elevation 2410±10 ft.).</u> Evidence for this stage is confined to abundant subrounded gravel exposed along the distal edge of a deeply-dissection topographic bench which slopes 10-13^o valleyward (fig. 6). One head-sized block of calcareous material found along the upper margin of this bench does not resemble any of the tufa found on lower shorelines and contains no snail shells. Topographic benches at similar elevation between Pleasant and Middle Park canyons lack rounded gravel and tufa but may correlate with this feature.

<u>F_1 (elevation 2298±10 ft.).</u> Evidence for this substage is a cut bench armored by a lag accumulation of boulders and cobbles and overlain by up to 15 feet of backset beds of subrounded gravel (fig. 8). This exposure is now separated by a 50-foot gully from the principal sequence of beaches and gravel

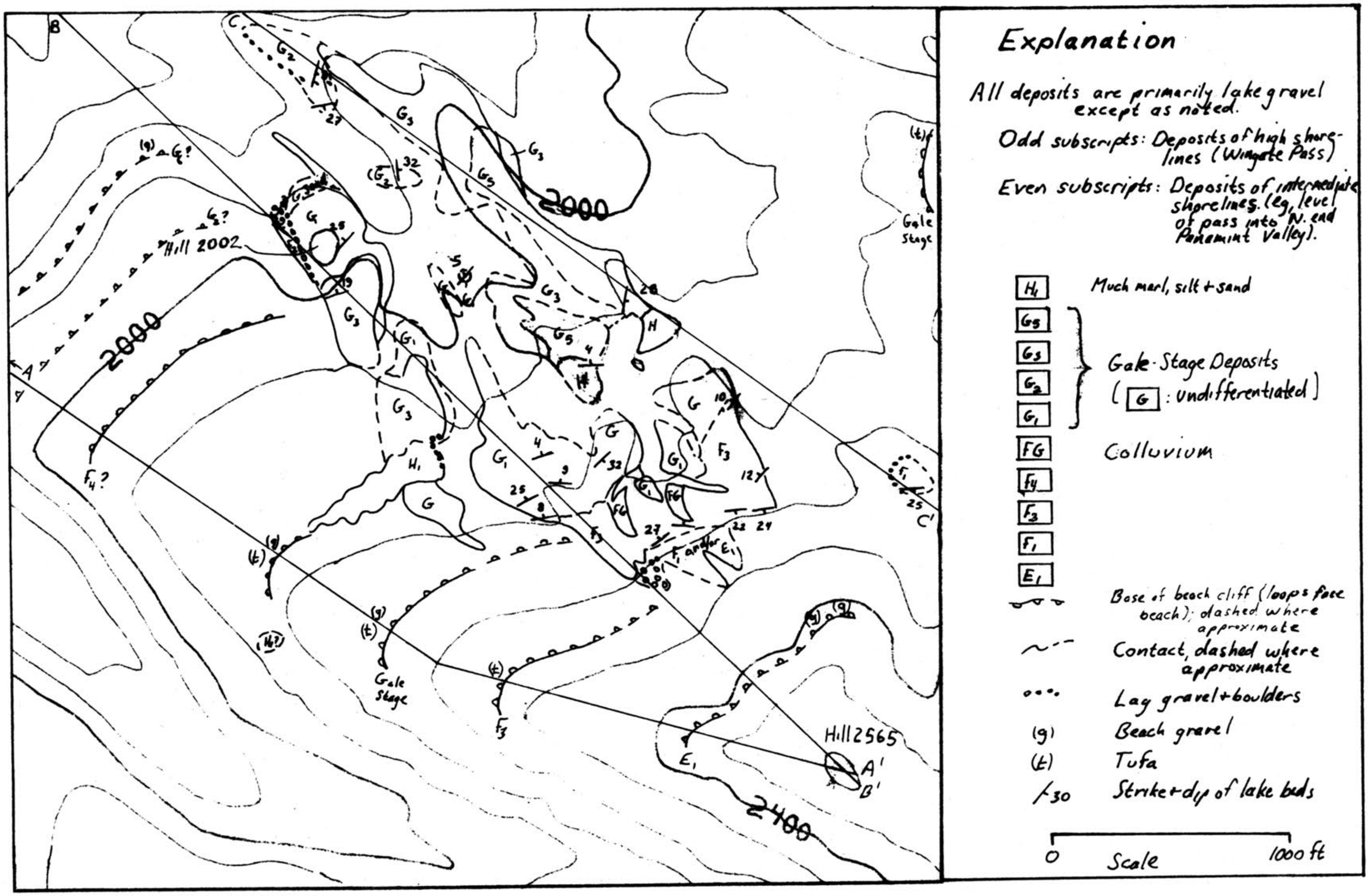

Figure 6. Geological map of lake deposits on the north side of Pleasant Canyon.

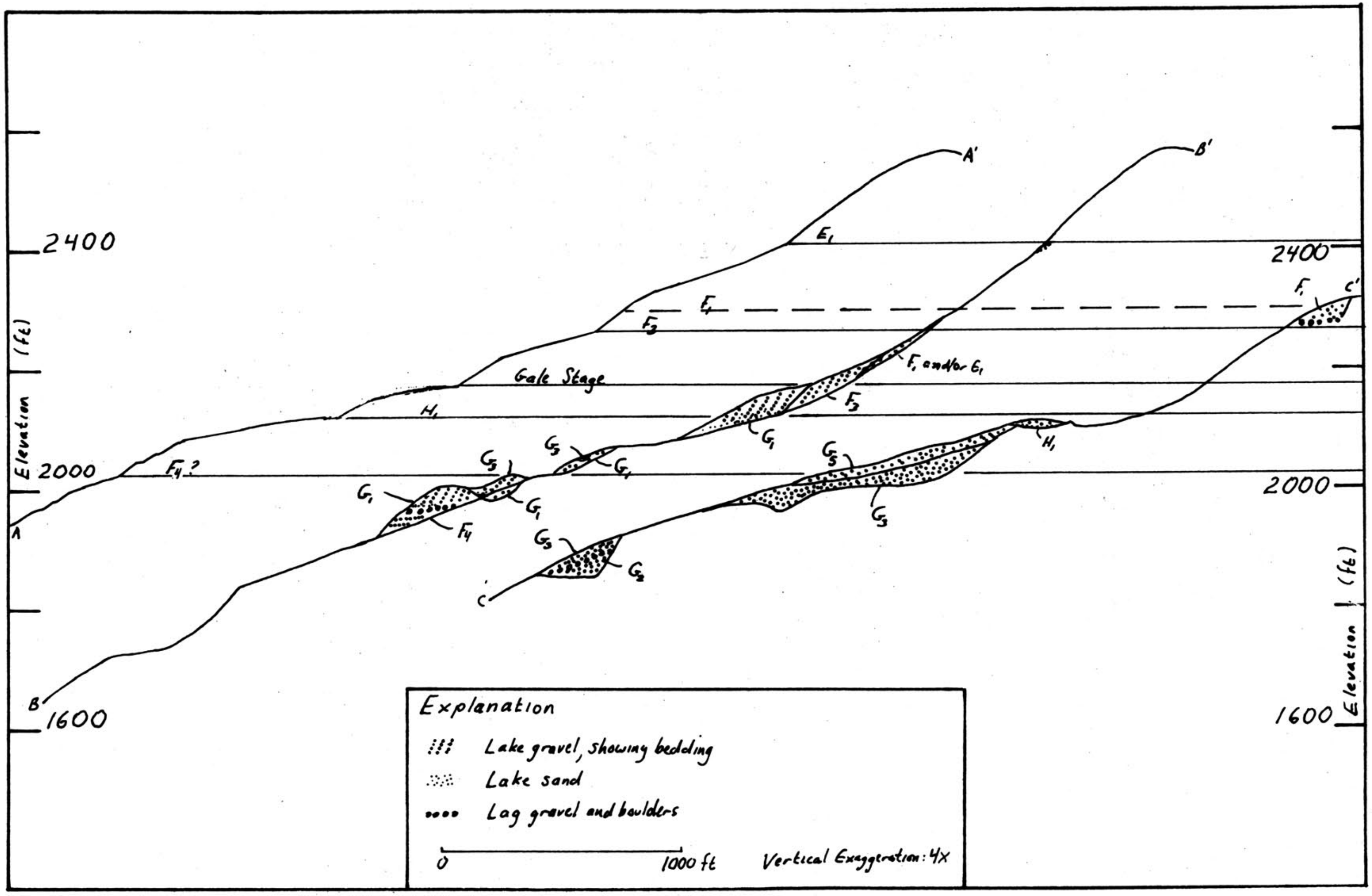

Figure 7. Geological cross sections of lake deposits on the north side of Pleasant Canyon.

deposits on the north side of Pleasant Canyon, where no shoreline can be found at a corresponding elevation. Deposits of subrounded gravel in the principal sequence at a proper elevation may represent an eroded E_1 deposit rather than an F_1 deposit.

F_3 (elevation 2265±10 ft.). Evidence for this substage is a wide bench, sloping seven degrees valleyward, from which a prominent gravel bar extends northeastward (fig. 6). This bar, of subrounded gravel, unconformably overlies a lag accumulation on the surface of a gravel deposit attributed to E_1 and/or F_1 substage. Nodose to lithoid tufa found along the distal edge of the F_3 bench contains no snail shells.

F_4 (elevation 2025+15 ft.?). Northeast-dipping lake gravel attributed to this substage is 15 feet thick, reaches 1990 feet elevation and is capped by a four-foot-thick lag deposit of boulders (figs. 7, 9). The F_4 gravel is older than the bottomset G_1 sand which overlies the boulders. The F_4 shoreline may be along the nip (elevation 2025±15 ft.) of a bench cut into fanglomerate to the south (fig. &), but this bench bears neither rounded gravel nor tufa and the F_4 gravel cannot be traced up to this bench. The F_4 gravel was probably deposited in a lake whose level was stabilized by overflow into north Panamint Valley. The possible F_4 shoreline lies about 240 feet below the F_3 shoreline, which suggests that the F_3 shoreline had been uplifted about 25 feet before the lake again rose and occupied the F_4 shoreline (240 feet modern elevation difference minus 215 feet difference in elevation of overflow sills equals 25 feet uplift of F_3 shoreline).

Gale-Stage Deposits and Shorelines

The prominent, high Gale-Stage shoreline was cut during lake stands whose level was stabilized by overflow through Wingate Pass. The earliest part of G_1 substage was probably stabilized by overflow across the 1930-foot bedrock lip beneath Wingate Pass and the rest of G_1, plus G_3 and G_5 substages, were probably stabilized by overflow through the modern 1977-foot outlet channel in Wingate Pass. The fainter, intermediate-level Gale-Stage shorelines were probably cut during lake stands whose level was stabilized by overflow across the sill (now 1715 ft.) into north Panamint Valley. The water level of lake stands at intervening elevations fluctuated too much and too often to leave identifiable records. Gale Stage is divided into five substages (G_1 -G_6). With one possible exception (G_3-G_5) the high substages are separated by distinct falls of water level from the Wingate Pass stabilization to the north Panamint sill stabilization.

G_1 (elevation 2177±10 ft.). Gale-Stage gravels lie along and downslope from a shoreline at this elevation (fig. 7). On the north side of the mouth of Pleasant Canyon, basal Gale-Stage gravels are nearly everywhere underlain by a bottomset sand which mantles an eroded surface (figs. 9, 10). This sand bed persists over an altitudinal range of more than 300 feet and is useful both as a marker for the base of Gale-Stage deposits and to distinguish them from deposits of other stages. In most places, the sand bed directly overlies eroded fanglomerate rather than older lake deposits, but at low elevation (~1900-1950 feet) it locally overlies a lag deposit of boulders developed on F_4 gravel (fig. 9). Here, snail shells in the sand yield a radiocarbon age of 33,700±500 B.P. (USGS-324); this is considered to represent a minimum age for the deposit. At high elevations (~2140-2170 feet) the sand locally

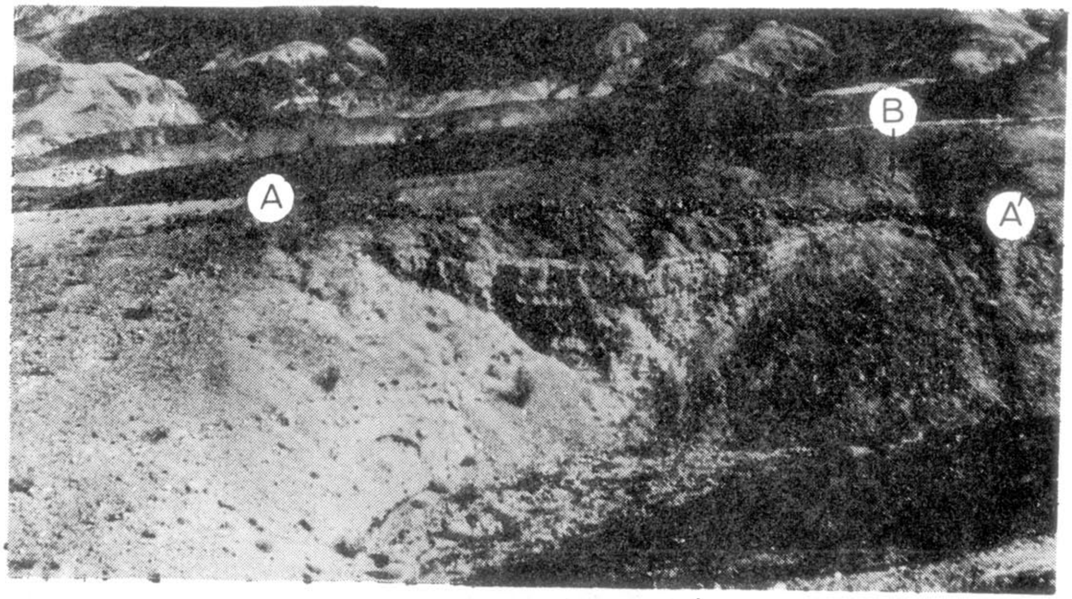

Figure. 8. F_1 bench. Looking northeast at the type locality north of Pleasant Canyon (fig. 6). Note the coarse lag boulders (A-A') on the cut bench (which has no topographic expression) and the backset bedding in lake gravel at the head of the bench (B). The gully in the foreground is about 50 feet deep and isolates this only outcrop of F_1 from all lake deposits of other stages.

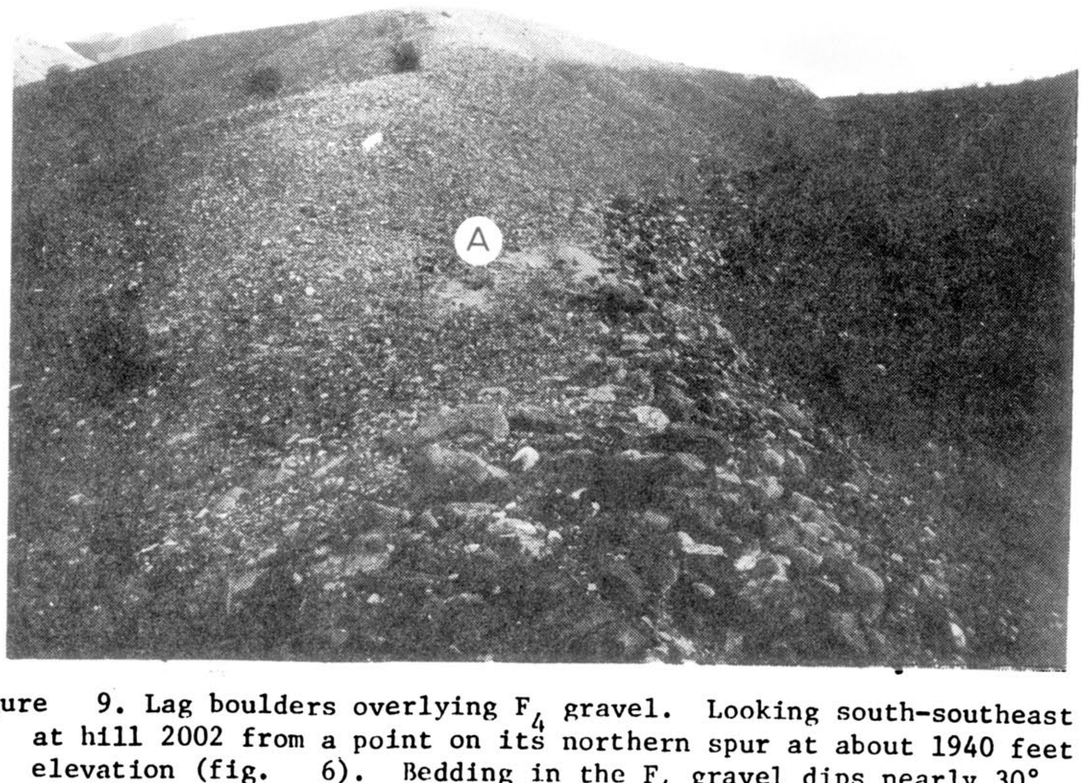

Figure 9. Lag boulders overlying F_4 gravel. Looking south-southeast at hill 2002 from a point on its northern spur at about 1940 feet elevation (fig. 6). Bedding in the F_4 gravel dips nearly 30° to the northeast. Bottomset sand of basal Gale-Stage (G_1) is exposed at the shovel (A). This sand overlies the lag boulders and interfingers upward with the foreset G_1 gravel beds, which dip to the northwest at about 25°. The gully on the right side of the photo now isolates the F_4 gravel from the F_4(?) shoreline above.

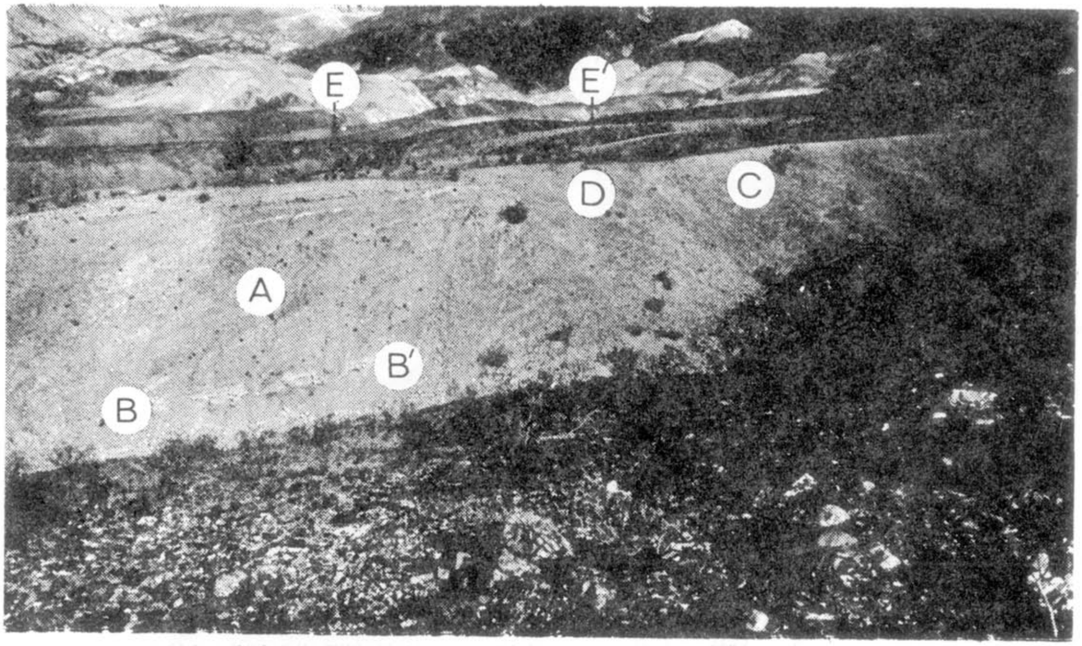

Figure 10. Foreseet beds of basal Gale-Stage (G_1) gravel. Looking northeast along the Gale-Stage shoreline north of Pleasant Canyon (fig. 6). The foreset G_1 gravel (A) interfingers with bottomset G_1 sand (B-B') in a gully wall about 30 feet high. These Gale-Stage deposits overlie F_3 gravel (C); this contact is covered but lies somewhere on the slope below (D). Note the accordance in elevation between the top of the G_1 gravel and the Gale-Stage shoreline in the distance (E-E').

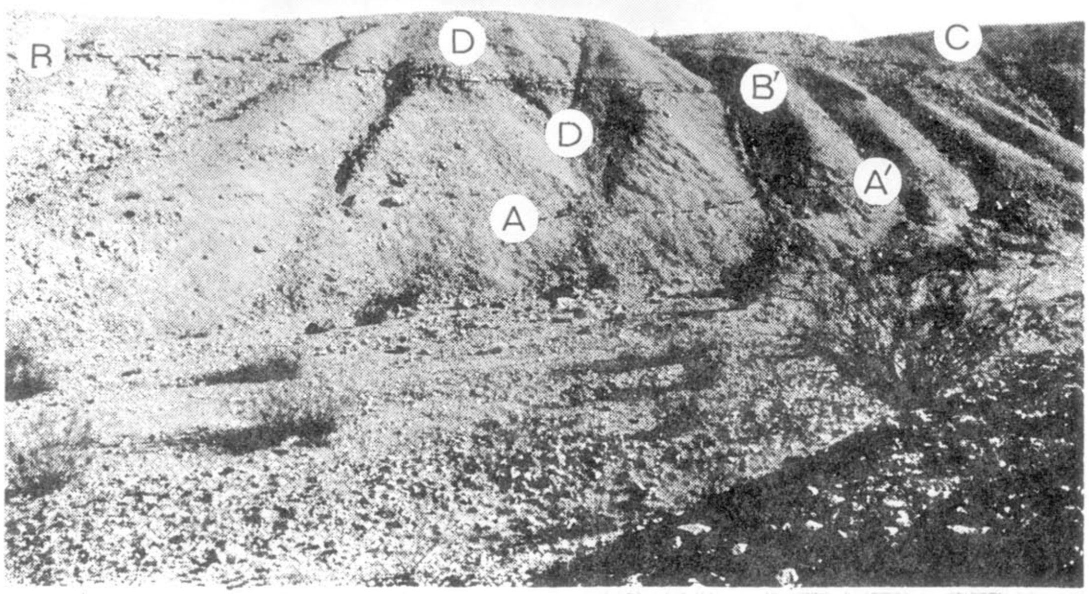

Figure 11. Deposit of G_2 gravel. Looking east at exposure in gully wall, about 60 feet high, whose brink lies at about 1920 feet elevation (fig. 6). Bottomset G_1 sand (A-A') underlies the lower of two G_2 gravel bodies, which are separated by a lag deposit (B-B')and overlain by G_3 gravel (C). Note the backset bedding in both the upper and lower G_2 bodies (D). Both bodies are interpreted as bars which formed across the gully mouth.

overlies subaerially-eroded F_3 gravel (fig. 10). The foreset beds of G_1 gravel interfinger with the bottomset sand (fig. 10) and at their highest extent rest directly on F_3 gravel or overlie a thin (one foot thick) layer of compact colluvium which locally mantles F_3 gravel.

Voluminous deposits of foreset gravel are found 500 to 2,000 feet south of Pleasant Canyon (fig. 5). They are continuously exposed from about 1800 to 2130 feet elevation but cannot be traced higher to the prominent Gale-Stage bench because they are mantled by a thick layer of bouldery mudflow debris. These deposits are attributed to Gale Stage because they lie at an elevation comparable to that of Gale-Stage deposits on the north side of Pleasant Canyon, and are assigned to G_1 substage because of their great bulk and relationships to probable G_2 deposits described below.

<u>G_2 (elevation 1920±20 ft.).</u> Downgully, near its lowest exposed elevation (~1870 ft.), the bottomset G_1 sand underlies two distinct bodies of backset (east- and south-dipping) gravel (G_2) which underlie G_3 gravel (figs. 6, 7). The upper part of the G_2 gravel overlies a lag deposit developed on the top of lower G_2 gravel beds, and both parts terminate against a gully wall cut into fanglomerate during pre-G_1 time (fig. 11). The highest elevations of the lower and upper G_2 bodies (1900 and 1920 feet, respectively) lie 277 feet and 257 feet, respectively, below the Gale-Stage shoreline. This suggests that they were deposited during a Gale-Stage phase stabilized by overflow into north Panamint Valley. The G_2 deposits may be remnants of bars formed across the gully mouth, and this substage lasted long enough for gullies to cut more than 30 feet into G_1 gravel and underlying fanglomerate (fig. 12). A shoreline bench at 1950±20 feet elevation may be related to the G_2 gravels, but the latter cannot be traced up to it (fig. 7). Shoreline benches at similar elevation (1930±20 feet) on the south side of Pleasant Canyon were cut into debris which may in part mantle G_1 (?) gravel. Deposits of subrounded gravel attributed to the 1930 and 1950 shorelines continuously exposed from 1800 to 1930 feet elevation are attributed to G_2 substage (fig. 3-5).

<u>G_3 (elevation 2177±10 ft. (?)).</u> Deposits of lake gravel (G_3) which overlie G_2 gravel are laterally continuous with gravel fillings in a northeast-draining gully cut during G_2 time (fig. 12). Here, G_3 gravel is underlain by up to 10 feet of G_3 sand, silt and marl above a thin, hard, calcareously-cemented crust on G_1 deposits exposed on the old gully wall. Elsewhere, G_3 gravel is underlain by silt above a coarse lag accumulation which marks the top of G_2 gravels. Although G_3 gravel cannot be traced with certainty higher than 2080 feet elevation, it is thought to have been deposited in a lake whose level was stabilized by overflow through Wingate Pass. Lacustrine gravel, either G_3 or G_5, overlies G_1 gravel and extends up to the Gale-Stage shoreline (elevation 2177 feet).

<u>G_5 (elevation 2177±10 ft.).</u> Deposits representing G_5 substage overlie G_3 gravel along a contact which is fairly smooth and marked by a slight topographic bench that probably represented differential erodibility of the two units (fig. 12b). This contact is locally identified by a lag deposit. Elsewhere it cannot be seen in shallow trenches cut through it. Because of the subtle nature of the G_3-G_5 contact and the absence of any identified G_4 deposits, G_3 and G_5 may both be deposits of high-lake stands, uninterrupted by any lower lake level. In any case, the G_3-G_5 interval was too short for noticeable erosion of G_3 deposits, and much shorter than the G_1-G_3 interval of erosion.

G_6 (?) (elevation 1890±25 ft.). A shoreline at 1895±20 feet has been cut partly into gravels below the 1930-ft. shoreline on the south side of Pleasant Canyon. It is associated with a gravel deposit on the brink of Pleasant Canyon and lies at similar elevation to a cut bench (elevation 1885±20 feet) on the north side of the canyon. This bench is littered with subrounded gravel (figs. 5, 7). These features and a shoreline at 1895±20 feet elevation at South Park Canyon, may represent the youngest stand of the Gale-Stage lake, a stand probably stabilized by overflow into north Panamint Valley.

Deposits Younger than Gale Stage

H_1 (elevation 2127±10 ft.). A narrow beach bar which overlies Gale-Stage deposits (G_3, G_5) on the north side of lowermost Pleasant Canyon grades southwestward into a tufa-littered bench cut into fanglomerate (figs. 6, 7). The bar's composition is pea gravel, marl, sand and silt, with locally-abundant snail shells. It occupies a broad, shallow, north-east-draining trough, cut mainly along the contact between fanglomerate and G_5 lake gravels, and is floored by a thin, hard unit of calcareously-cemented sand (fig. 13). This trough represents shallow (about 10 feet) dissection of Gale-Stage deposits by a broad, northeast-draining gully. This G_5-H_1 interval of subaerial exposure and dissection was probably shorter than the G_1-G_3 interval, if relative duration can be measured by relative depth of dissection.

The minimum age of the H_1 bar is 34,300±1,000 B.P. (USGS-202), based on the radiocarbon age of its contained snail shells of the genera Carnifex and Lymneae. Another part of the same sample of shells yielded a radiocarbon age of 31,150±1,400 B. P. (I-6543). Because a small amount of contamination by young carbonate in these aragonitic shells could make them seem much younger than they really are, the older date is taken to represent their minimum age, and the younger is assumed to be more contaminated. Note that these dates straddle the date on G_1, which is clearly much older than H_1 on stratigraphic grounds.

I_1 (?) (elevation 2040±40 ft. ?). Evidence for an overflow stand of the I-Stage lake is equivocal, despite the abundance of I-Stage nodose tufa at intermediate elevation (1500-1800 feet) along the foot of the Argus Range. Similar tufa locally overlies Gale-Stage deposits up to 1890 feet elevation south of lowermost Pleasant Canyon, where the I-Stage shoreline may be indicated by benches at 2020±20 and 2040±20 feet elevation (fig. 5). These weakly-developed benches are on the surface of the bouldery mudflow debris which covers both the Gale-Stage gravels and the H_1 shoreline. They bear neither tufa nor rounded gravel and may not be of lacustrine origin. The topographic scarp above the lower bench diverges from a scarp of unknown origin which retains its height as it descends to the southwest. A more likely example of an I_1 shoreline is a sharply-incised bench (nip elevation 2065±20 feet) at South Park Canyon. A narrow bench on the north side of Pleasant Canyon lies at this elevation (fig. 15) but cannot be traced to the south side. This 2065 bench might have been buried beneath the debris which covers all older units on the south side.

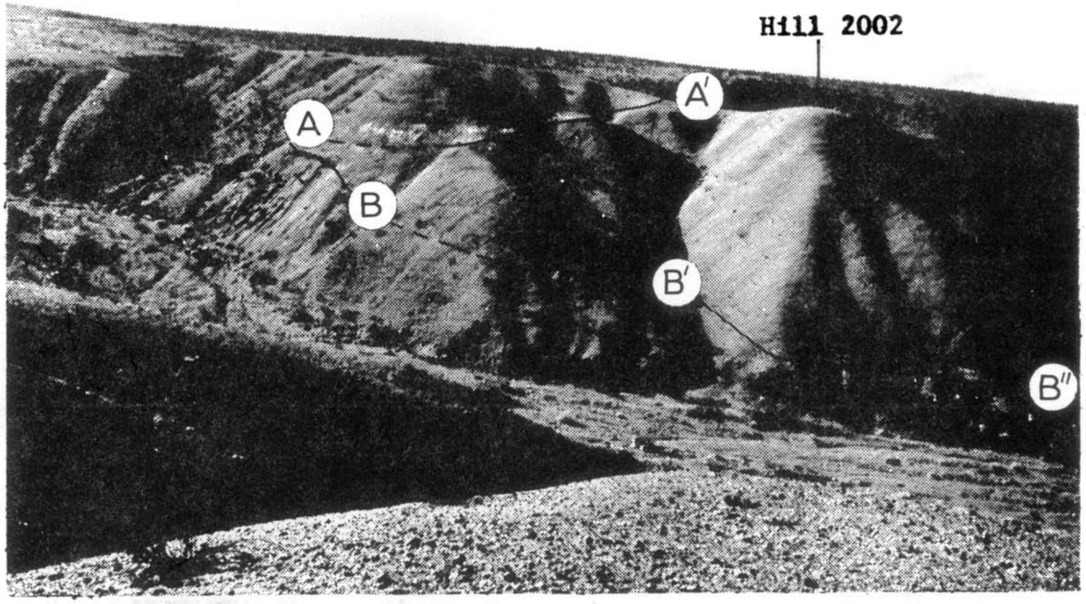

Figure 12a. Looking southwest at filled G_2 gully. This gully (A-A'), about 30 feet deep, was cut into foreset beds of G_1 gravel during an intermediate (G_2) stand of Lake Panamint and later filled with G_3 deposits (fig. 6). The bottomset G_1 sand (B-B'-B'') descends westward (right) almost to the floor of the modern gully, here about 100 feet deep.

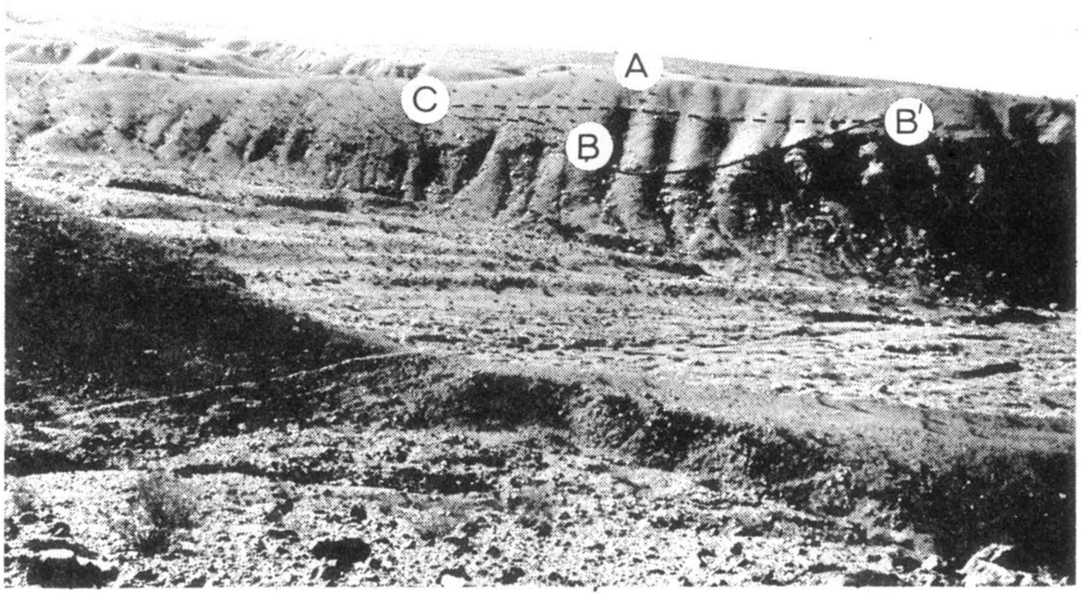

Figure 12b. Looking southwest at lower reach of G_2 gully. Figure 12a was taken from point A. The gully (B-B') is here cut into fanglomerate. The G_3-G_5 contact (C-B') is slightly accentuated by erosion and some lag gravel.

Figure 13. Looking southwest at H_1 bar. Slope at left is in older fanglomerate; the topset(?) beds at right are G_5.

Field Guide to Stop 2

Figure 14 shows the route of the field trip through nearshore deposits on the north side of Pleasant Canyon. We plan to stop where each new unit is first encountered and where relations between units are seen best; these sites are marked by the unit symbols. Photographs in this text are marked by their respective figure numbers in parentheses. The uphill leg will go mostly upsection; the downhill leg will cross progressively younger shorelines attributed to the various lake stages. See figures 6 and 7 for a geologic map and cross sections of these deposits and shorelines.

LOW SHORELINES

Introduction

The highest low shoreline is the most prominent of the low shorelines and is variously marked by wave-cut cliffs five to ten feet high, by bars of subangular gravel, by deposits of silt and clay, and by benches broader than those of lower shorelines (fig. 15). This shoreline has an elevation of about 1165 feet on both sides of Panamint Valley except where it has been deformed near the Panamint Valley fault zone (elevation range here is 1145 to 1186 feet). No water levels above this shoreline can be found below 1520 feet elevation. On steep slopes, like those at South Park Canyon, up to 20 shorelines can be found below the highest low shoreline, but on gentle slopes, like those on the west side of Panamint Valley, less than three can be found. No tufa or snail shells have been found along any of the low shorelines, but a few blocks of nodose tufa were found along the Happy Canyon road at 1080 feet elevation (fig. 1). The low shorelines are by far the freshest-looking in Panamint Valley and are probably the youngest. They are designated I_2 substage.

Paleohydrologic Significance

Paleohydrologic calculations suggest that even the low shorelines are of lake stands too large to have been sustained by local runoff. This judgement is based on the equilibrium conditions needed to sustain a low, late-Wisconsin lake stand in north Panamint Valley--this basin, with roughly half the watershed of the south basin, sustained a lake of seven to 15 square miles area. (see R. S. U. Smith, 1975, ch. 5, for discussion). The area of the south-Panamint lake filled to 1160 feet elevation is 67 square miles; the wettest possible Wisconsin conditions could sustain a lake now higher than 1100 feet elevation (area about 50 square miles). More conservative reconstruction of these conditions suggest a lake level of 1040 to 1055 feet and lake area of 13 to 26 square miles. The insufficiency of local runoff to sustain the observed lake level suggests that local runoff was augmented by Sierra Nevada runoff overflowing from Searles Lake. If so, these low shorelines above 1100 feet elevation probably formed during one or more of the four overflow episodes of Searles Lake recognized by G. I. Smith (1976) to have occured during the interval 23,000 B.P. to 12,000 B.P. Because evidence cited previously for I_1 stage suggest a deep, if not overflowing, stand of Lake Panamint early in this interval, as does evidence from elsewhere in the valley, it seems most likely that the highest low shorelines (I_2 Stage) represent the last, short overflow episodes of Searles Lake at 13,000 and 12,000 B.P.

Field Guide to Low Shorelines at South Park Canyon (Stop 3)

The low shoreline progression at South Park Canyon shows both erosional and constructional features, as well as faulting which both predates and postdates shoreline formation. The uphill leg of the field trip route traverses the lower shorelines and some overlying alluvium to the cut bench of the highest shoreline (fig. 15). Followed south, this cut bench leads to a bar; a gulley in the middle of the bar displays both foreset and backset gravel. Note that the bar on the opposite side of the gulley is about five feet higher then on the near side--the gulley follows a fault which postdates the bar. The downhill leg of the route crosses several fault scarps whose character was subdued by wave action in the lake and hence predate the latest low lake stand.

HIGH PAIRED SHORELINES

Introduction

The highest shoreline in many parts of Panamint Valley is actually a pair of shorelines--the higher much more prominent than another one, typically 25 to 50 feet lower in elevation. Tufa on the higher shoreline is mostly lithoid; tufa on the lower shoreline is mostly dendritic.

Wildrose-Trona Road

These shoreline pairs are seen best on the slopes above the Wildrose-Trona Road (fig. 16), where their NW-SE profile (fig. 17) shows that they have been faulted and otherwise deformed.

Stratigraphic relations suggest that the lower shoreline is older than the higher shoreline. A body of lacustrine gravel, separated by a colluvial or alluvial layer into upper and lower units, is found in the S 1/2 NW 1/4 sec. 12 (Fig. 16; pt A on fig. 17). The upper lacustrine unit, whose lowest exposed elevation is 2000±10 feet, extends eastward and upward to the higher shoreline at 2040±10 feet elevation (fig. 18). This upper unit is about five feet thick, cemented by calcium carbonate and made of subrounded pebbles and cobbles, 70 per cent of which are muscovite granite gneiss (fig. 19). The colluvial or alluvial layer, made of subangular pebbles, is poorly exposed but may reach a thickness of five or ten feet.

The lower lacustrine unit, about 10 feet thick, is cemented by calcium carbonate only in its upper part and is made of subrounded pebbles, all of metasedimentary rocks but none of gneiss (fig. 18). The highest elevation (2000±10 feet) reached by this lower unit is 20 feet lower than the lower shoreline (2020± feet). The age of the lower unit is probably the same as the age of the lower shoreline. The absence in the lower unit of clasts of gneiss so common elsewhere on the higher shoreline suggests that the lower unit represents a remnant of a body of locally-derived gravel which filled the gully before gneissic gravel reached this point.

Deformation

Although lower in elevation than the higher shoreline, the lower shoreline seems to have been deformed more; its present structural relief on the

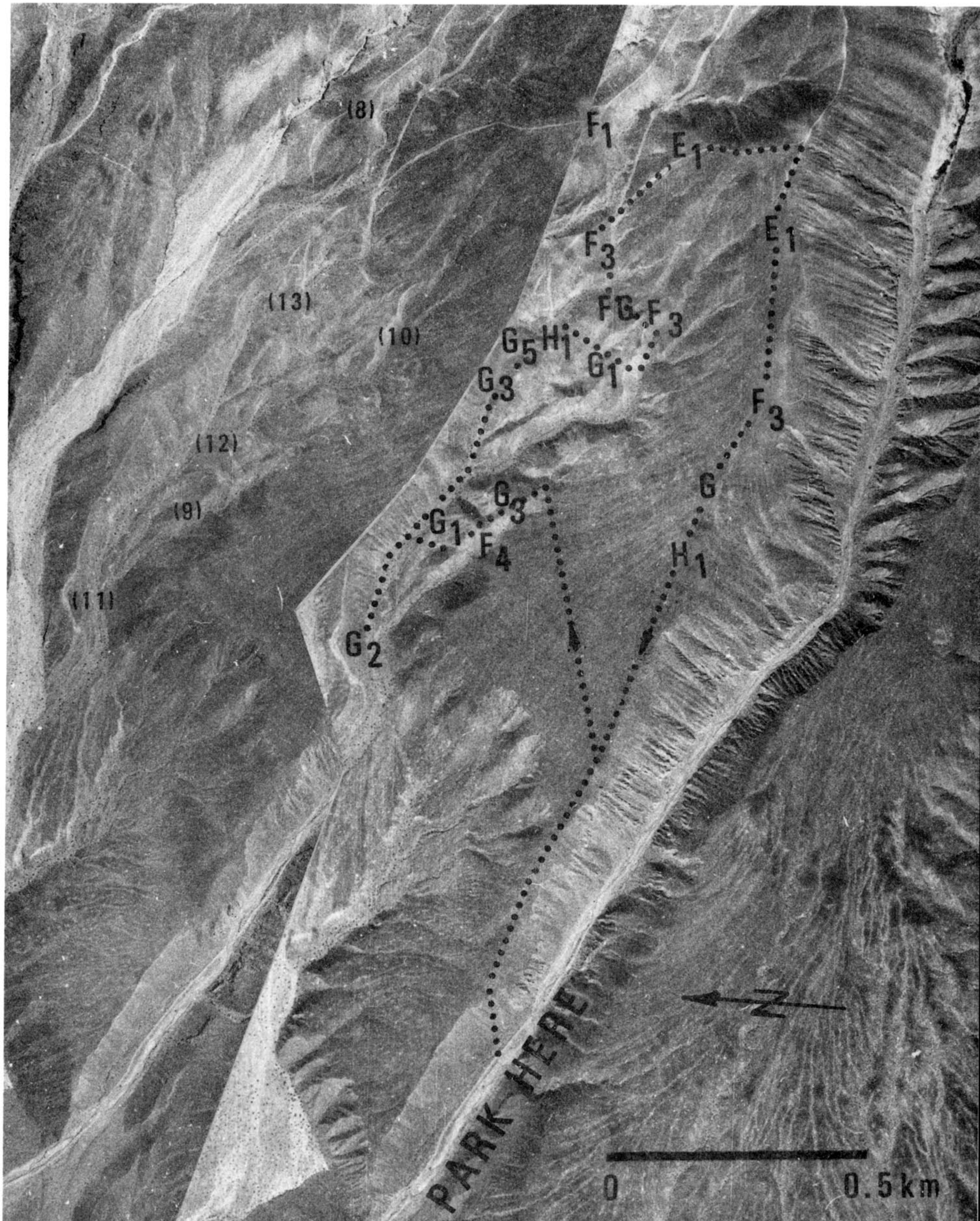

Figure 14. Stereogram of lake deposits at Pleasant Canyon, showing field-trip route. (GS-VEDP 1-1,1-155; 7-10-76)

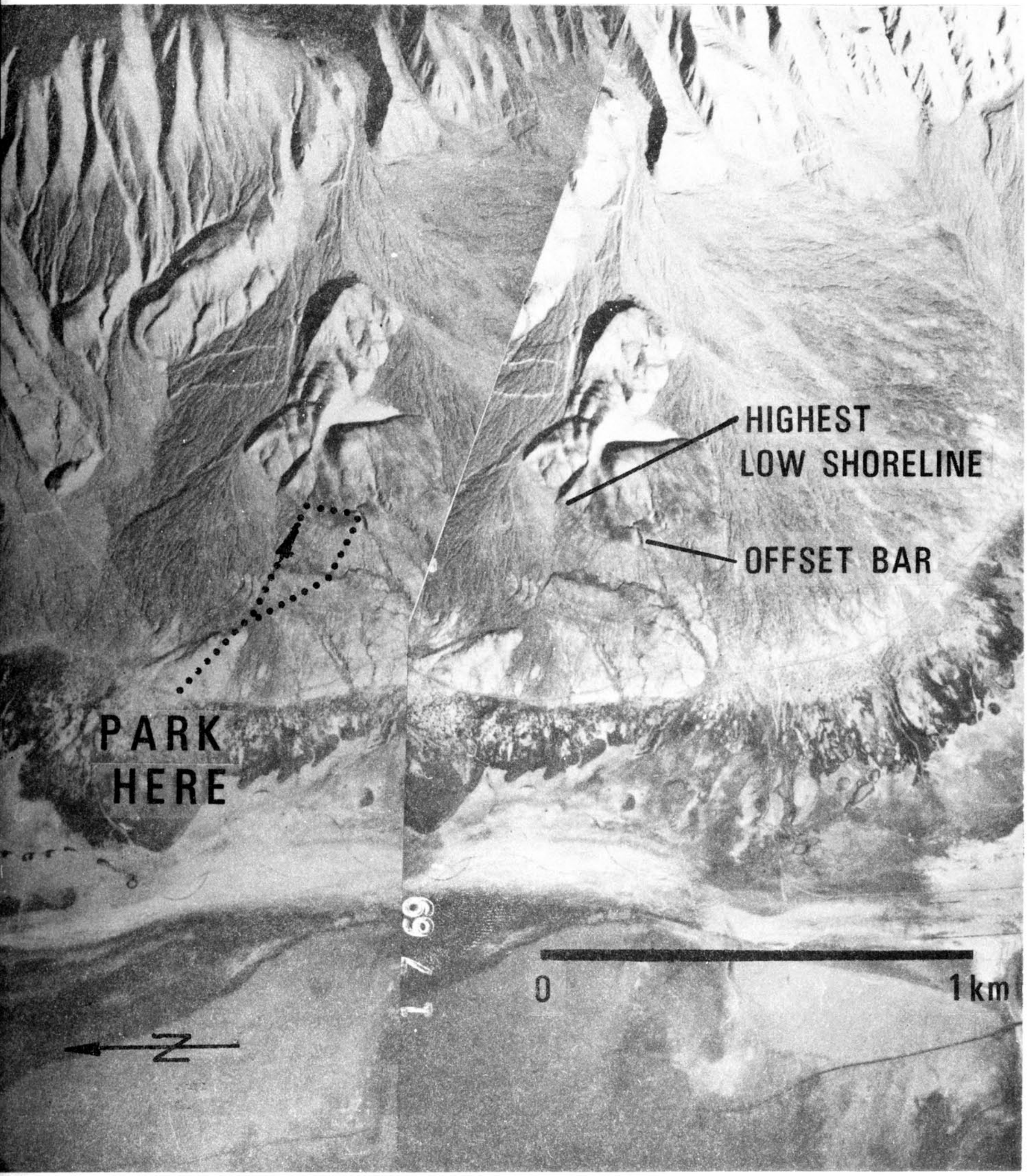

Figure 15. Stereogram of low shorelines at South Park Canyon, showing field-trip route. (Photos PTV-20-2-70&71, 1-7-69, courtesy of D.B. Slemmons)

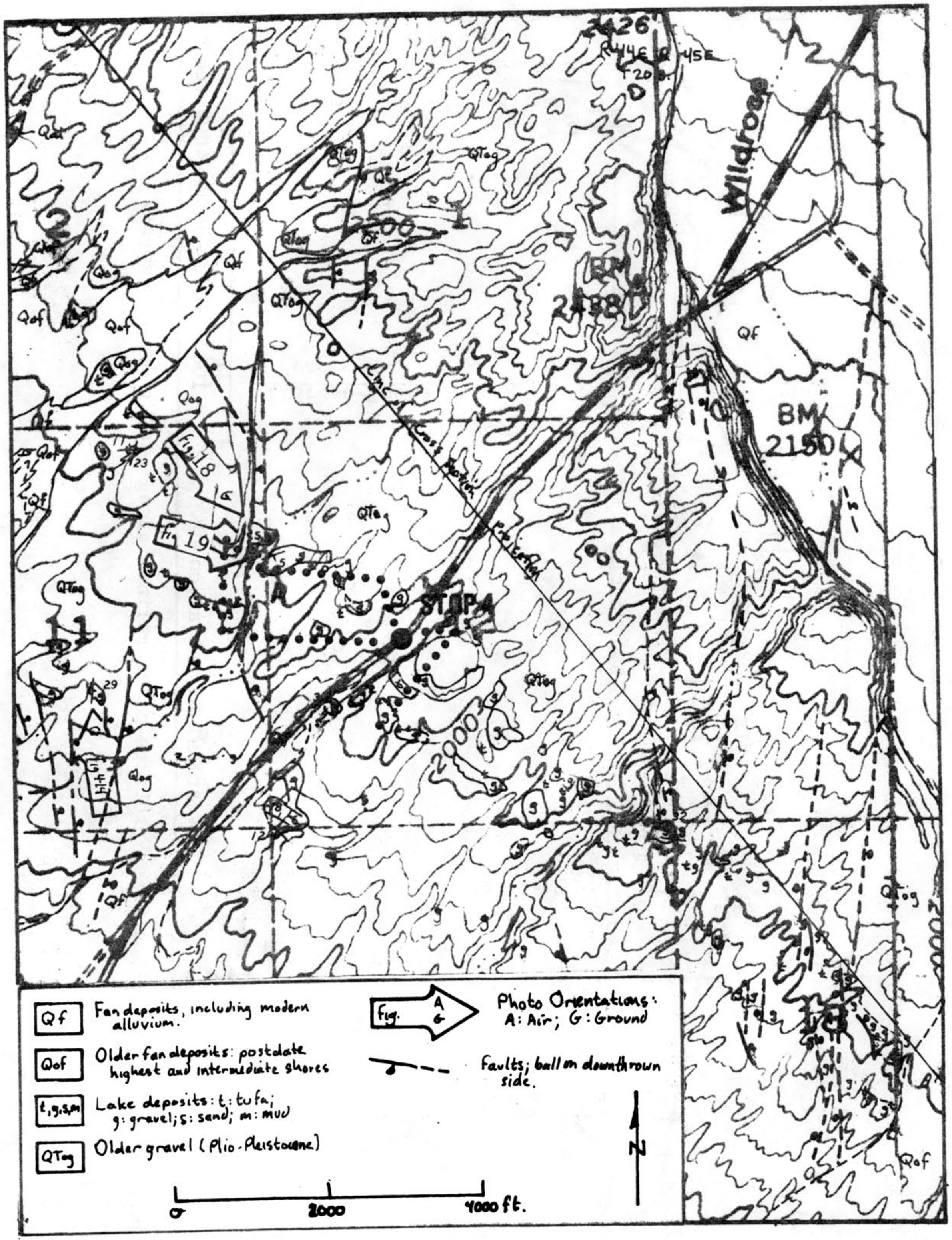

Figure 16 . Geological map of the southeastern Wildrose segment.

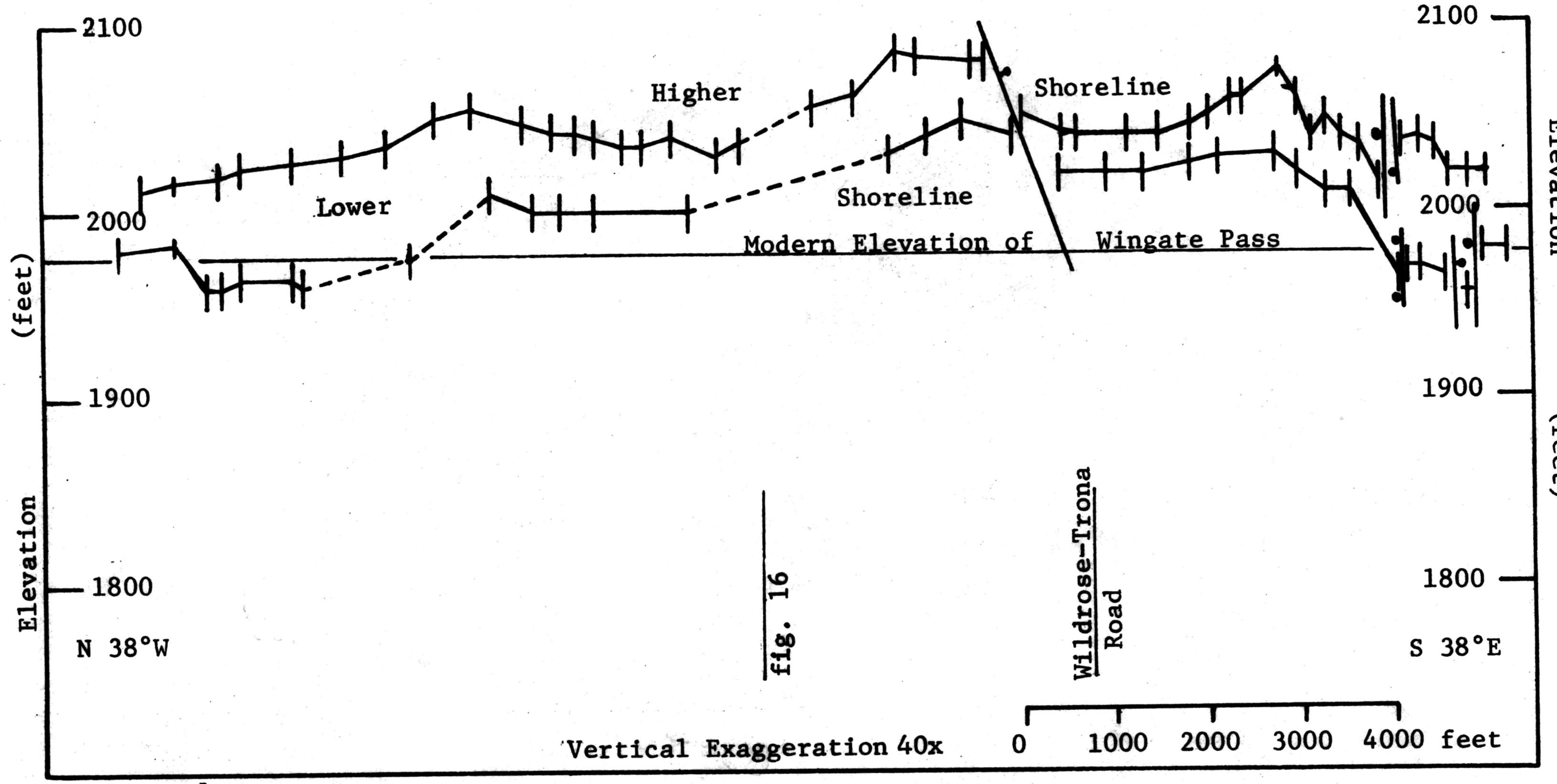

Figure 17 . Northwest-southeast profiles of shorelines along the Wildrose segment.

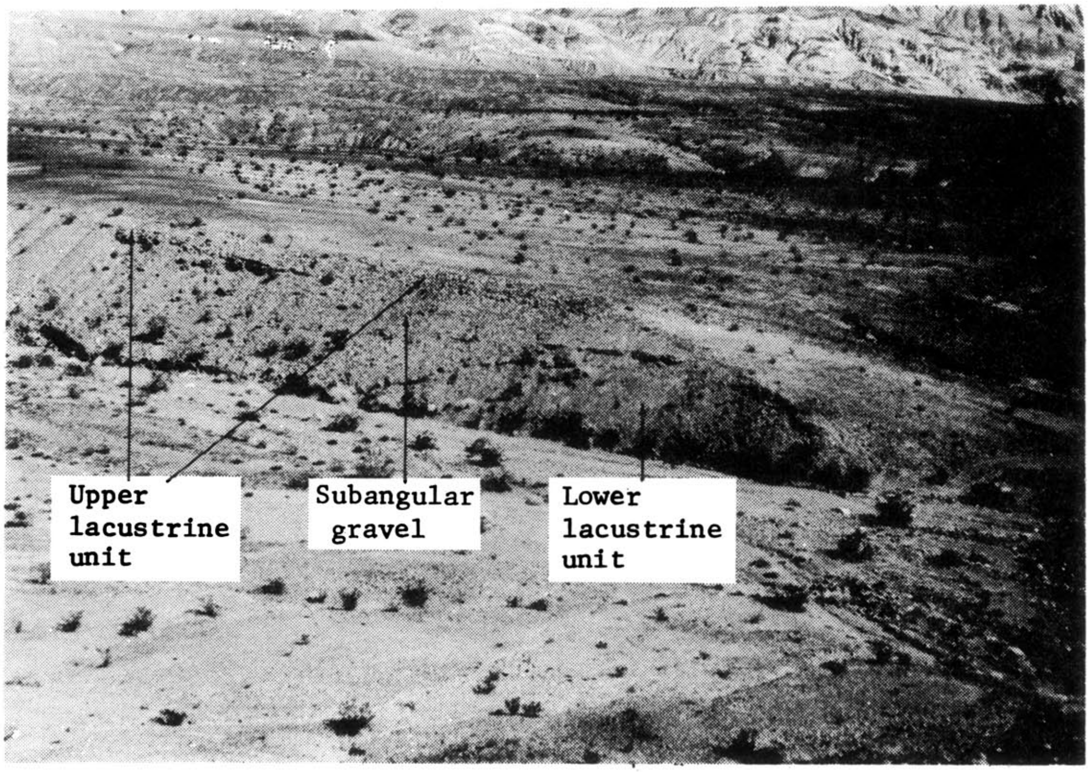

Figure 18. Lake gravels of two ages north of Wildrose-Trona road. View is southeast towards a gravel body which extends from below the level of the middle shoreline up to the higher shoreline. The lower lacustrine unit contains abundant subrounded to rounded pebbles, none of which are gneiss. Subangular colluvial or alluvial gravel overlies the lower unit. The upper lácustrine unit is of cemented gravel whose subrounded to rounded cobbles are largely of gneiss (fig. 19).

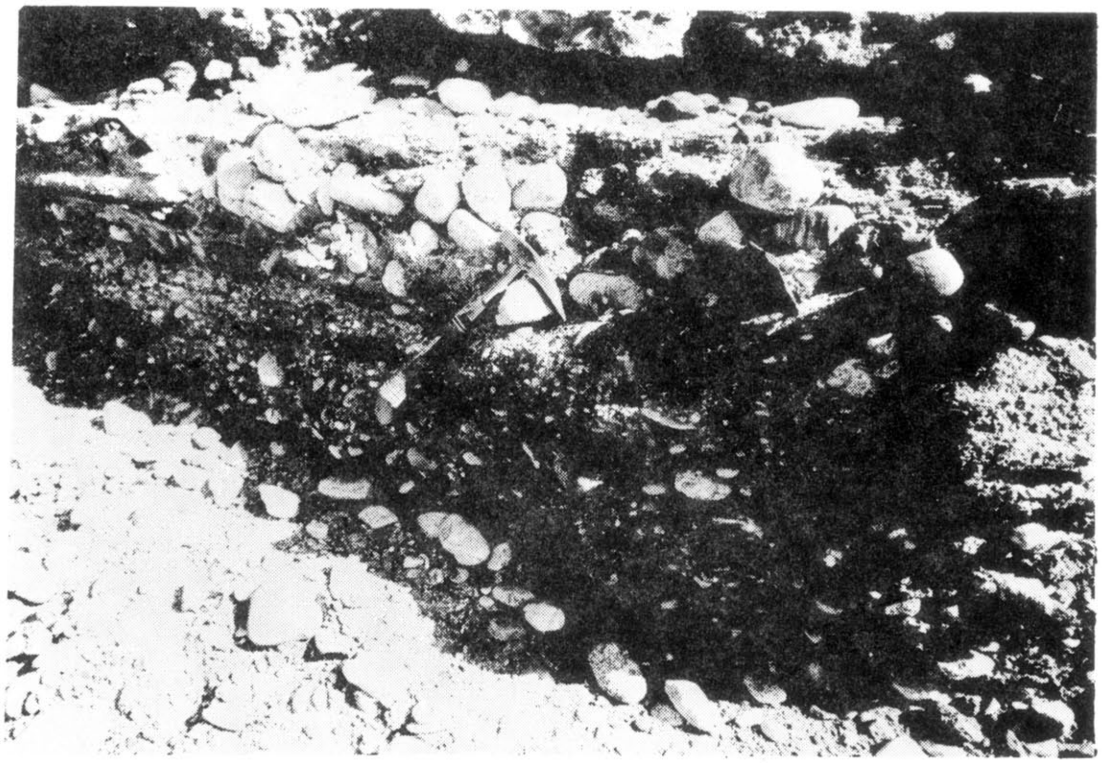

Figure 19. Cemented lake gravel.
This is the upper unit in Figure 18, attributed to the higher shoreline. Note the abundance of light-colored gneiss cobbles.

Wildrose segment is 90 feet, versus 73 feet for the higher shoreline (fig. 17). The elevations of high shoreline pairs throughout Panamint Valley show a similar relation when plotted against each other (fig. 20) The relation between elevation of these pairs is remarkably constant throughout the valley, regardless of whether their present elevation is above or below the level of Wingate Pass. The slope of the line connecting these pairs is 1.26, indicating that the lower shoreline has been deformed 1.26 times more than the higher shoreline and is thus older, perhaps by a factor of 1.26.

Both the lower and higher shorelines are attributed to Gale Stage. The lower shoreline was probably cut during early G_1 substage by a lake stand stabilized at the level of the bedrock lip now buried beneath Wingate Pass, and the higher shoreline cut during later substages of Gale Stage stabilized at the level of Wingate Pass, 47$\pm$16 feet higher than the level of the bedrock lip.

In uplifted areas, the higher shoreline is probably a composite feature, reoccupied and deepened during subsequent substages by wave attack on the risen block. In areas of greatest uplift (e.g. Pleasant Canyon), the prominent high shoreline composite may be superposed onto the lower shoreline and represent a composite of all Gale-Stage high stands (fig. 21).

Field Guide to Stop 4

The high paired shorelines can be seen on either the northwest or southeast side of the Wildrose-Trona road. If time is long, we plan to see them on the northwest side, where stratigraphic relations indicate older age of the lower shoreline (figs. 18, 19) and where they have been cut by a fault (point A on fig. 17). If time is short, we plan to see them on the southeast side of the road, where their relative age cannot be determined. Both versions of this stop are shown on Figure 16.

PLUVIAL CHRONOLOGY

History of Lake Panamint

Bases for Reconstruction

The history of Lake Panamint is reconstructed from two types of records to which an implicit time scale can be assigned; a) the succession of shorelines and lake deposits at Pleasant Canyon, with a time scale based on shoreline uplift rates, and b) logs of cores from three holes drilled in Panamint Valley and logged by Smith and Pratt (1957) and Motts and Carpenter (1968), with a time scale based on estimated sedimentation rates.

The composite record of fluctuations in the level of Lake Panamint plotted at the top of Figure 22 is based on the shoreline record and the three core records plotted below. The "time" scale of the composite record is in units of net shoreline uplift at Pleasand Canyon. Net uplift probably reflects age in years, but such ages are not shown on Figure 22 because uplift rates are not precisely known; estimated ages of lake stages are listed on Table 2.

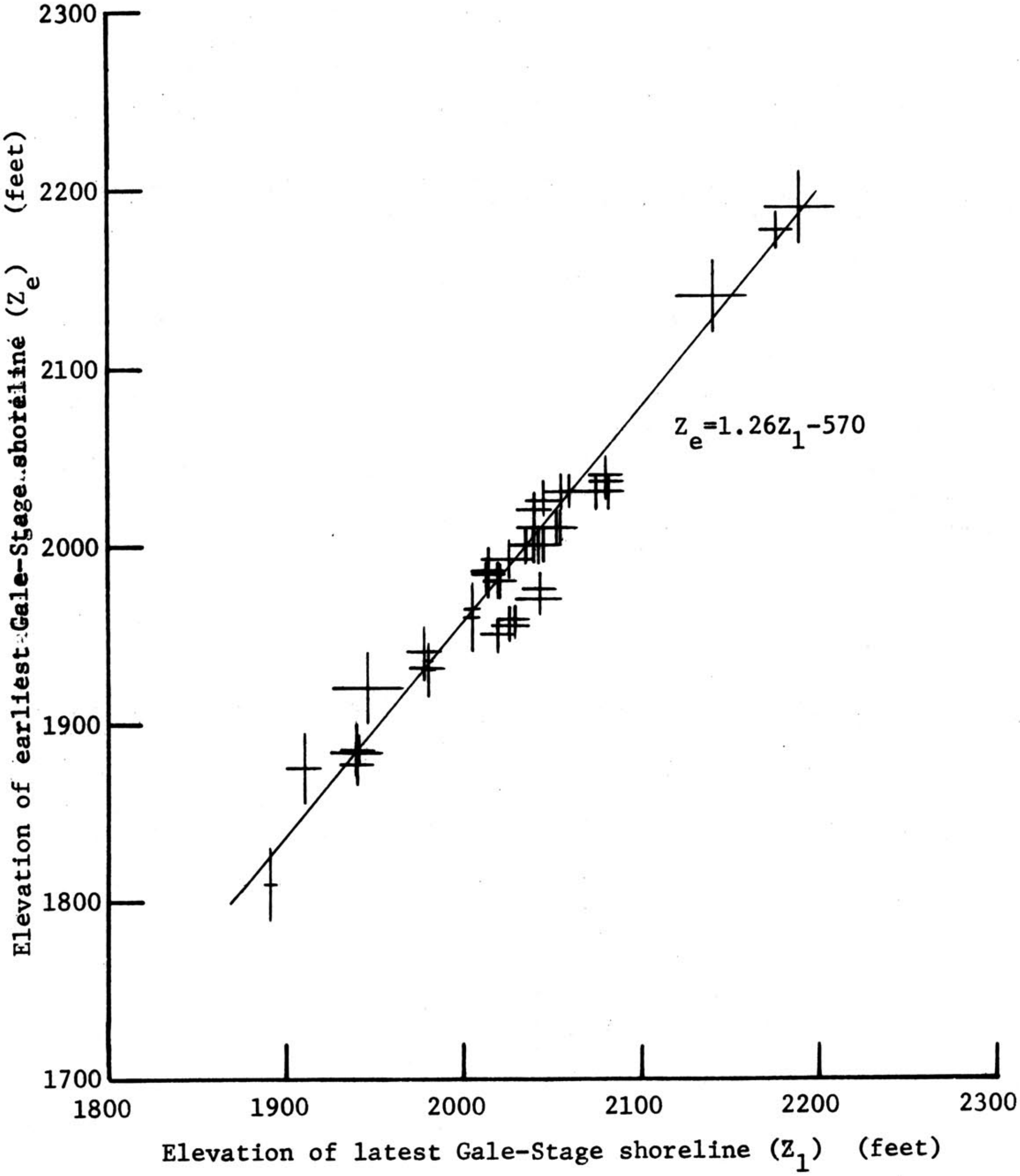

Figure 20 . Elevation of earliest Gale-Stage shoreline as a function of elevation of latest Gale-Stage shoreline.

(1) Cutting of G_1 bench at 1930-foot level of bedrock lip in Wingate Pass. Deposition of G_1 gravel below bench.

(2) Mudflow buries bedrock lip in Wingate Pass. Lake level rises, overtops mudflow and cuts modern outlet channel into top of mudflow (elevation 1977±1 ft).

(3) New bench cut at higher level of new outlet channel.

(4) Width of new bench and height of new wave-cut cliff increase as wave erosion tries to keep pace with range uplift.

(5) Old G_1 bench uplifted to level of new bench and its width is added to the width of the new bench, making the prominent composite bench seen today.

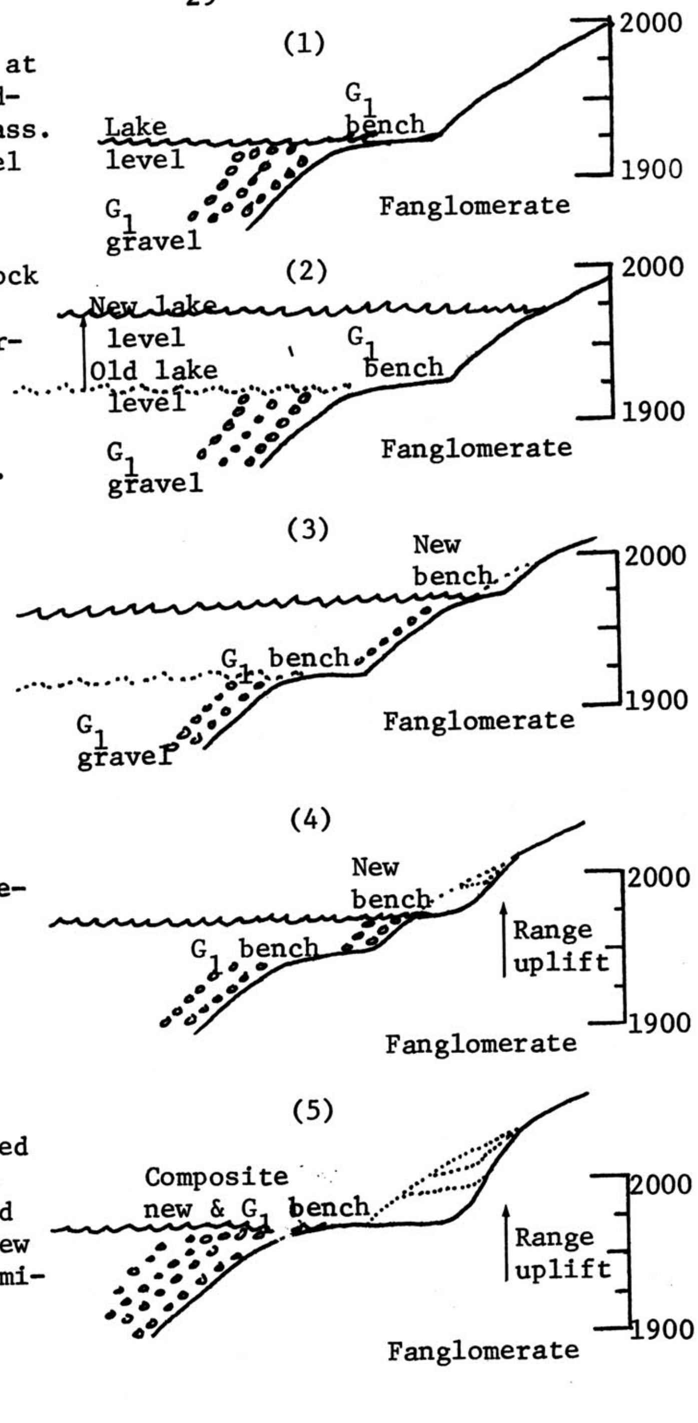

Figure 21 . Possible explanation for development of prominent Gale-Stage shoreline at Pleasant Canyon.

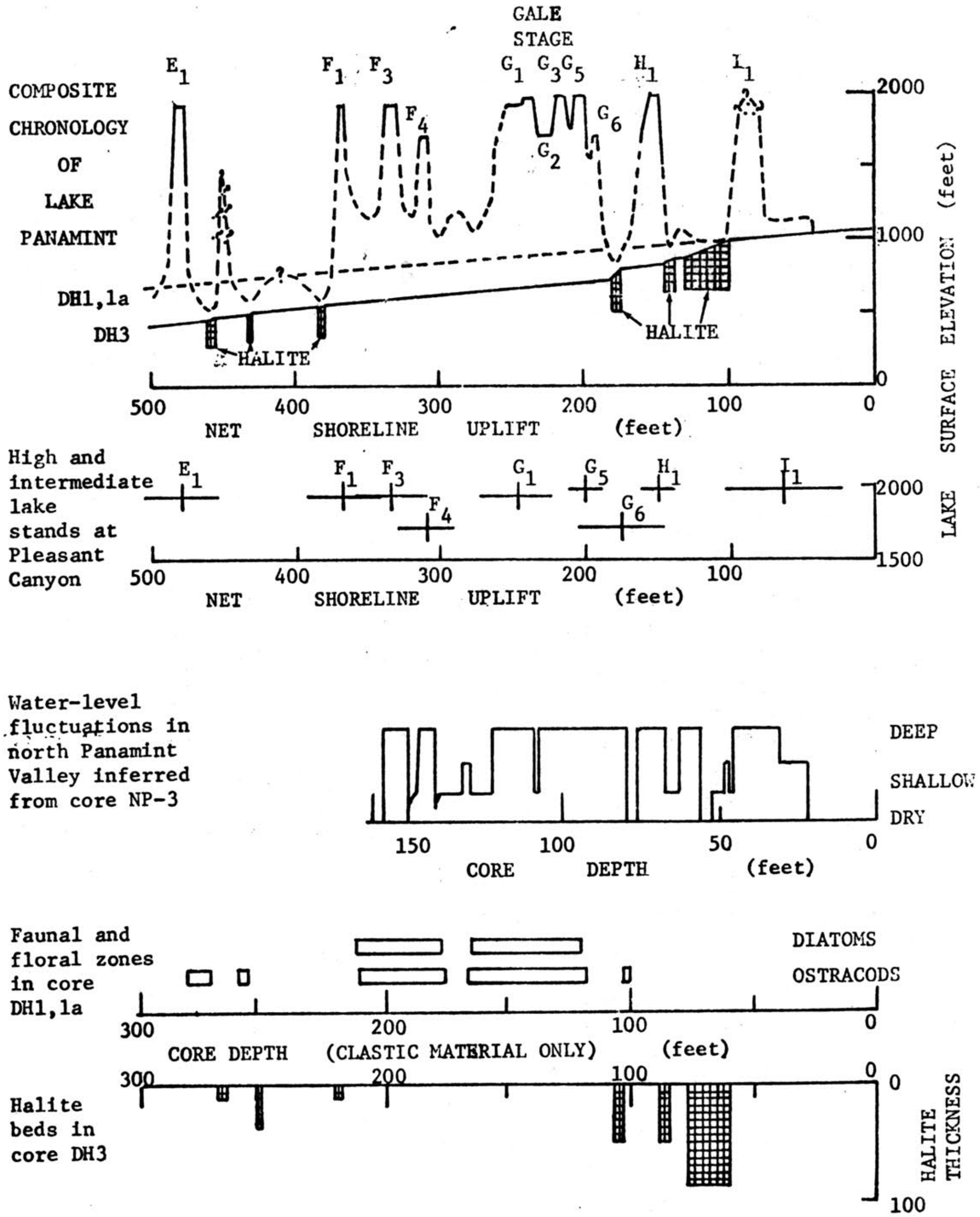

Figure 22. Construction of the composite pluvial chronology of lake Panamint (top) from high-shoreline and core records (below).

Composite Lake History

Panamint Valley was occupied by deep lakes during four pluvial episodes separated by periods of desiccation intense enough to cause sodium chloride deposition (fig. 22). The first pluvial episode (E-Stage), although brief, was wet enough to cause Lake Panamint to overflow into Death Valley. Inspection of the DH1, 1a and DH3 core logs suggests that two high E-Stage lake stands were separated by a short period of salt deposition, but only one E-Stage shoreline has been recognized. The succeeding interpluvial period (EF) was twice as long as the next-longest interpluvial (HI). The lowest water levels during the EF interpluvial probably occurred at its beginning and end, the only parts of this interpluvial marked by salt beds. The second pluvial episode (F and Gale stages) lasted four times longer than any other pluvial episode (E, H, I). The combined duration of overlowing lake stands was shorter during the first half (F Stage) than during the second half (Gale Stage) of the second pluvial episode,as judged by the greater prominence of the Gale-Stage shoreline and larger bulk of Gale-Stage deposits. The F-Stage lake probably spilled into Death Valley for short periods on two occasions, whereas the Gale-Stage lake probably overflowed during much of its duration. A period of low lake level separated F Stage from Gale Stage, as indicated by the absence of ostracods and diatoms from this interval on core DH1, 1a, but complete desiccation did not occur, for salt is lacking in this interval in core DH3. A brief episode of salt deposition separated the end of Gale Stage from the beginning of H Stage, when Lake Panamint once again spilled briefly into Death Valley. H Stage was followed by a period of almost-continuous salt deposition, totalling 130 feet in thickness in core DH3, excluding enclosed clastic material. This indicates more complete desiccation than during the two previous interpluvial periods (EF and GH), even though the EF interpluvial period was longer. The salt deposited during the HI interpluvial period was probably introduced into the lake mostly during F and Gale stages, but complete desiccation did not occur until the HI interpluvial period. The I-Stage lake may have overflowed briefly into Death Valley, but evidence for overflow is equivocal. Firm evidence does indicate that the lake rose at least to within 150 feet of overflow level. During much of I Stage, the lake's level was below 1560 feet in north Panamint Valley and below 1165 feet in south Panamint Valley. These or still lower levels were probably maintained until final desiccation of the lake.

Radiometric and Extrapolated Ages of Lake Stages

Method

The discernible record indicates that Panamint Valley filled to overflowing more than 110,000 years ago. This conclusion is based on extraposition from radiocarbon dates showing minimum ages for deposits attributed to Gale Stage (G_1?, >50,000 B.P., Hubbs et al 1965, p. 93-96) and to H Stage (H_1, >34,300±1000 B.P.) If youngest possible age is plotted as a linear function of shoreline uplift at Pleasant Canyon, then a line defined by the origin, H_1 and G_1 (fig. 23) defines the youngest possible age of other lake substages whose shoreline uplift is known. Two assumptions underlie Figure 22; 1) uplift rates have been constant; and 2) of all carbonate materials, shells yield the most reliable radiocarbon dates. However, any carbonate date greater than 25,000 B.P. must be considered indicative of minimum age because

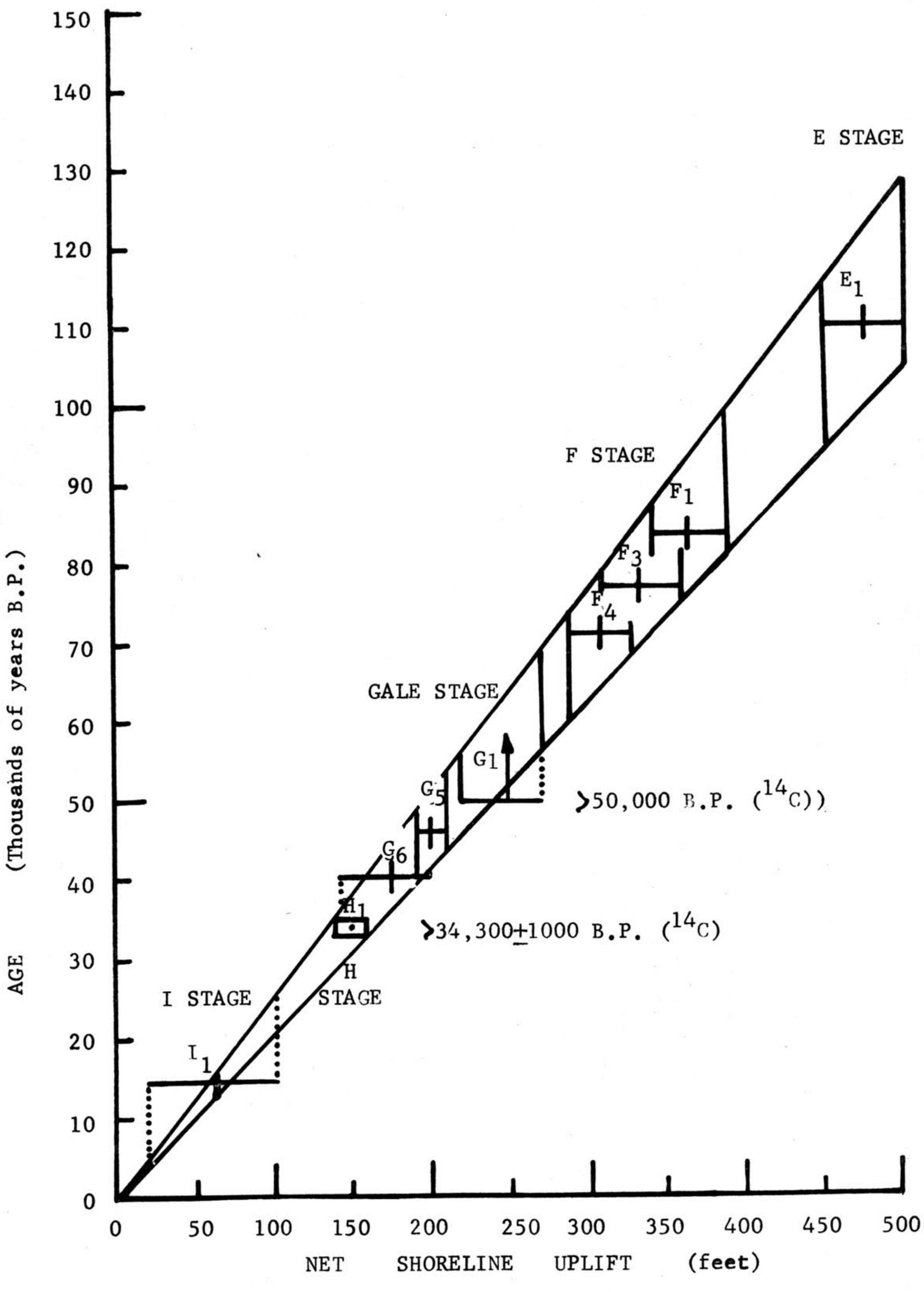

Figure 23. Radiocarbon and extrapolated ages of lake stages.

Table 2

Age and duration of lake stages

Stage	Extrapolated Age (Years B.P.)	Uncertainty Range	Probable Duration (Years)
I_1	15,000	4,000-26,000	—
H_1	34,300±1000 (^{14}C)		—
Gale Stage			About 17,000
G_6	40,000	29,000-52,000	
G_5	46,000	39,000-54,000	
G_1	56,500	50,000-69,000	
F Stage			About 13,000
F_4	71,500	60,000-84,000	
F_3	77,500	64,000-94,000	
F_1	84,500	71,000-100,000	
E Stage (E_1)	111,000	95,000-130,000	

NOTE: These ages apply to recognized high and intermediate lake stands defined by shorelines at Pleasant Canyon, except for I Stage. Because the shorelines were being cut as the range underwent uplift, erosion destroyed part of the evidence for the uplift. Thus age, calculated in uplift, is younger than it would be otherwise, and most ages are probably biased towards a younger age rather than greatest age. The age given for G_1 substage probably dates the youngest part of that substage prior to raising of the outlet level of Wingate Pass. The probable ages of G_1 and G_5 substages are consistent with the proportion (1.26) relating magnitude of G_1 deformation to magnitude of G_5 deformation throughout Panamint Valley.

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F_4	71,500	60,000-84,000	
F_3	77,500	64,000-94,000	
F_1	84,500	71,000-100,000	
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NOTE: These ages apply to recognized high and intermediate lake stands defined by shorelines at Pleasant Canyon, except for I Stage. Because the shorelines were being cut as the range underwent uplift, erosion destroyed part of the evidence for the uplift. Thus age, calculated in uplift, is younger than it would be otherwise, and most ages are probably biased towards a younger age rather than greatest age. The age given for G_1 substage probably dates the youngest part of that substage prior to raising of the outlet level of Wingate Pass. The probable ages of G_1 and G_5 substages are consistent with the proportion (1.26) relating magnitude of G_1 deformation to magnitude of G_5 deformation throughout Panamint Valley.

young carbon has probably contaminated the sample (Thurber, 1972; app. A). Three dates from the published literature (Hubbs et al, 1965, p. 93-6) are on snail shells from deposits in northern Panamint Valley attributed to Gale Stage (Smith, 1975, chs. 3,4). One of these dates LJ-985, >45,000 B.P.) is from snails in marl which postdates the early G_1 substage on the northern Wildrose segment. Another data (LJ-973), >50,000 B.P.) is from snails in marl near the base of Gale-Stage deposits on the southern Big Four segment, and the third date (LJ-981, >50,000 B.P.), from the northern Big Four segment, is on snails from marl uncertainly attributed to Gale Stage.

Chronology

The chronology of pluvial Lake Panamint derived from extrapolation of radiocarbon dating is presented on Table 2. If the method is valid, these ages and durations of lake stages still represent minimum values because they are based on radiocarbon dates which probably represent minimum ages.

The overflow event at 111,000 years B.P. (E Stage) was followed by a period of generally-interpluvial conditions which lasted about 25,000 years. The combined F and Gale stages lasted about 45,000 years until about 40,000 B.P., without any episode of desiccation intense enough for salt to be deposited on the lake bottom. Subsequently, the lake level rose at about 34,000 B.P., to overflow briefly into Death Valley (H Stage). Water levels were probably very low during the next 10,000 years when 130 feet of halite were deposited on the lake bottom. This interpluvial period was followed by the I-Stage pluvial, which lasted about 15,000 years. The lake was possibly deep enough only during the earliest part of this period to overflow into Death Valley. Lake levels were low during the rest of this interval, which ended about 10,000 B.P., as determined from the only radiocarbon dates on plant material collected from Panamint Valley (Berger and Libby, 1966).

ACKNOWLEDGMENTS

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