FRIENDS OF THE PLEISTOCENE

33rd Annual Runion, 1970

May 23 or 24, 1970.

& I)

Potential stops on the Auto Road (A,B/ and walking trip stops 1 to 12 counterclockwise around the summit of Mt. Washington, N. H. Other lettered stops C to H are possible extras for you to visit when you can. Dated references are to pictures or diagrams you have in references by R. P. Goldthwait, except that 1971 is not complete and diagrams are included here.

Leaders:

Richard P. "Dick" Goldthwait (Ohio State Univ.) general glacial geology
George D "Don" Bailey (SCS Hyattsville) soils
Brian K "Brian" Fowler (AMC & Tilton Acad.) naturalist-geologist
Thomas B. "Tom" Goldthwait (Dartmouth, Cabin & Trail) mountaineer-geologist

START. A. Glen House, Pinkham Notch at 1620': . . U-valley Wisconsin glaciation covered the highest peaks above you -- Mt. Washington to the west, is 6288' above sea level; the cols between peaks have striae and roche moutonnée S40E. Here, 4000' below, the ledges are even better polished and striated but toward S 0° to 20W. into glacially rounded Pinkham Notch. Basal ice swung 60° to 180° (S40E ± 40°) to get around this mountain mass. Was this ice doing a snake dance under the S40E ice up high? or did it wind around through valley in a nunatak stage?

This is the oldest high mountain road in this country, opened just 109 years ago. Between Mileposts 1 and 2 the road pits are in typical gray mountainside till 85% sand and rock sizes. Enroute to Mile 4 poorly sorted bedded kames are excavated for road material.

Mixed hardwood forest gives away to spruce and birch by the 3rd Milepost and these shorten to scrub forest by the 4th Milepost. There is no timberline but stunted spruce which may have 100 to 200 rings. All the bedrock is Littleton Formation, a tightly folded syncline of mica schists. By mineral-chemical identification with low grade metamorphic fossiliferous rocks in Connecticut Valley these are Devonian. It has 3 divisions; you will be on the upper one, metamorphosed from sand and mud layers.

PAUSE: B. Chandler Ridge, Great Gulf local glacier trough and Northern Peaks: glacial action.

The majestic peaks across this valley (Mts. Jefferson, Adams, Madison) were glaciated lightly but not rounded! Pink granite erratics from the Northwest are found all the way up the west slope of each mountain. For some reason (perhaps dead ice) the sides facing this way, southeast, are barren of all erratics.

In the valley before us was once a different kind of glaciation. Tributaries opposite have fine cirque bowls, and Great Gulf has a beautiful U-shape.

Since it extends for 5 miles, the glacier was at least that long, snowline was at least as low as 3300 feet and climate was at least 14°F (8°C) cooler in summer, than it is today. By projecting upper valley slopes, it is estimated this mountain glacier excavated at least 600 feet (180 m) depth in most places. On the other hand the Chandler Brook Valley just below you is a V-shape., fluvial valley, cut simultaneously with mountain glaciation. All local glacial valleys and cirques face north, east, and south with the lowest on the north signifying westerly winds and a critical snowlimit.

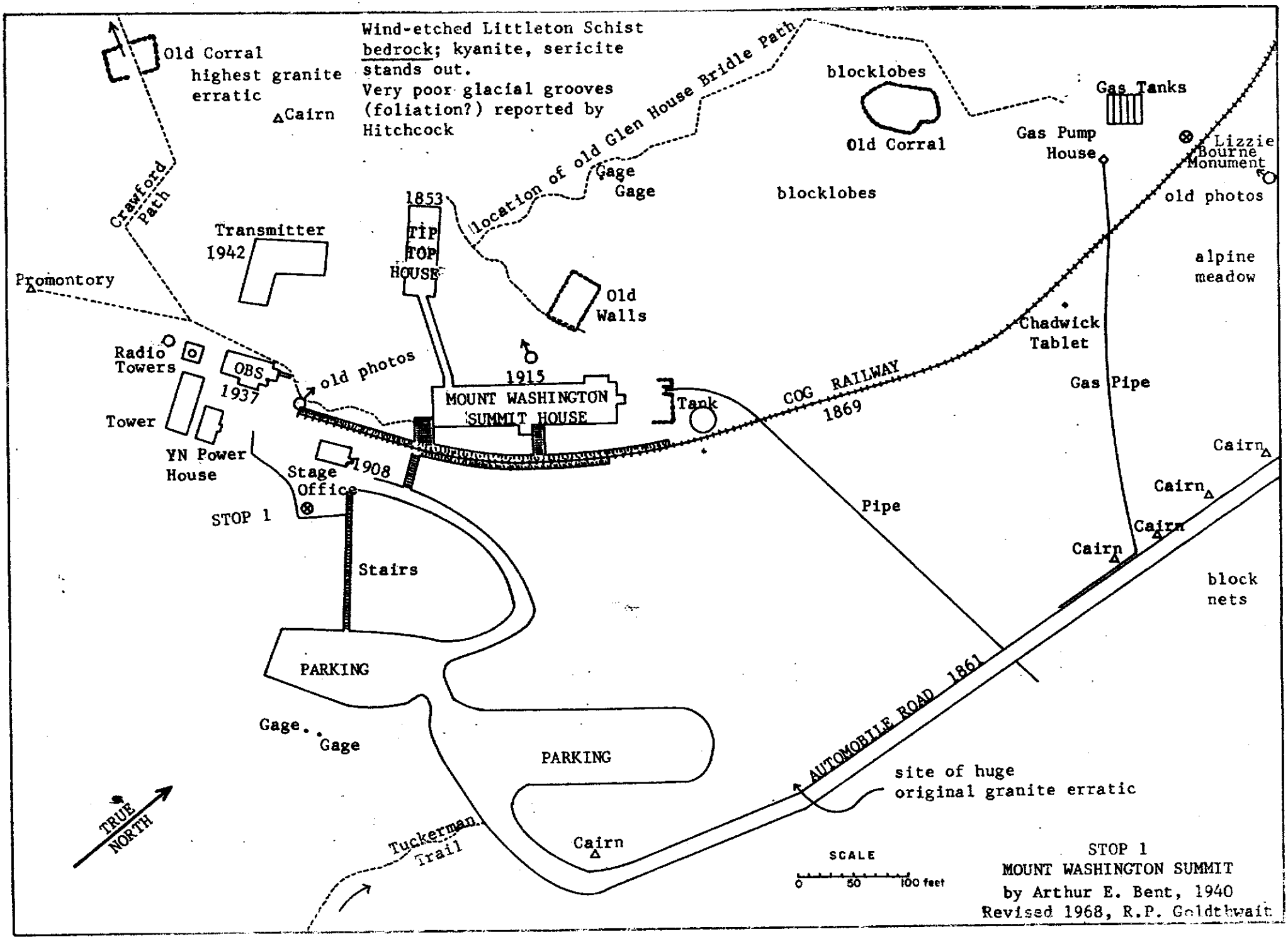
From here on up beautifully : folded mica schist and thin-bedded quartzite is seen at every turn (Littleton Formation). Some have big andalusite, staurolite and sillimanite crystals.

Between Mileposts 4 and 6, finely polished and striated ledges are passed and on one are potholes demonstrating water action at the margin of continental ice sheet during nunatak stages above 4000'. However, bedrock above Milepost 6 is all broken by frost and the slopes are more and more covered by felsenmere. Its lower limit is very sharp, below us (east). Patterned sorted soil (block stripes, polygons, and lobate terraces) become better developed also on "grassy" stretches from Mileposts 6 to 8, above 5300'.

STOP 1. Top of Mt. Washington, 6288': erosion surfaces, continental ice.

This is the highest peak in northeastern USA. On a clear day one can discern three sorts and ages of erosion surfaces: (1) the presidential Upland, which is preserved only in an undulating shelf flanking this peak and Mt. Jefferson at 5000' to 5500'. It may be the last vestige of Tertiary (?) erosion surface (Fig. 2A) accordant with dome-like peaks nearby, or it may represent especially rapid high altitude erosion ("altiplanation") throughout Pleistocene time. (2) Below this on the ridge ends and especially on the west side are broad Pliocene (?) valley slopes (1940, Fig. 2) (3) Finally there are the sharp narrow deep Pleistocene age cuts by streams on the southwest (1940, Fig. 8) and by local glaciers on the north, east, and south (1940, Fig. 5, and 1970, Fig.). Note asymmetry of Great Gulf due to the westward dip of beds and foliation. (4) The top of Mt. Washington was covered by continental ice sheet in Wisconsin time because building excavations underneath the felsenmere reveal good clay till with few erratics (1939, p. 13). Glaciation altered the high peaks very little except to increase the asymmetry of Mt. Monroe (SW), to produce little basins like Lakes-of-the-Clouds below (SW), and to round lower peaks (Mts. Clay or Pleasant, 1940, Fig. 3).

The age of continental glaciation isbelieved to be Wisconsin because depth of oxidation is minimal and erratics are well preserved. (Goldthwait, 1970) One unsolved question is: was it early Wisconsin if the sharp lower limit of felsenmere indicates a prolonged nunatak stage, or, is that intense frost work limit a one-stage product of downslope solifluction? Botanists suggested long ago that this arctic flora moved south ahead of continental ice and became lodged and isolated "endemics" here upon retreat. But must there have been a refugium here, at least since early Wisconsin time, as argued by Geum peckii, Potentilla robinsiana, Houstonia caerulea var. faxonorum?


Old Corral
highest granite erratic
Cairn
Wind-etched Littleton Schist bedrock; kyanite, sericite stands out.
Very poor glacial grooves (foliation?) reported by Hitchcock
Crawford Path
Transmitter 1942
1853
TIP TOP HOUSE
location of old Glen House Bridle Path
Gage
Gage
blocklobes
blocklobes
Old Corral
Gas Tanks
Gas Pump House
Lizzie Bourne Monument
old photos
alpine meadow
Promontory
Old Walls
Chadwick Tablet
Radio Towers
OBS 1937
old photos
1915
MOUNT WASHINGTON SUMMIT HOUSE
Tank
COG RAILWAY 1869
Gas Pipe
Tower
YN Power House
1908
Stage Office
STOP 1
Cairn
Cairn
Pipe
Cairn
Cairn
Stairs
block nets
PARKING
Gage
Gage
PARKING
AUTOMOBILE ROAD 1861
site of huge original granite erratic
TRUE NORTH
Tuckerman Trail
Cairn
SCALE
0 50 100 feet
STOP 1
MOUNT WASHINGTON SUMMIT
by Arthur E. Bent, 1940
Revised 1968, R.P. Goldthwait

Except for known fill (path around end of railroad) and building disturbance of schist blocks, the other blocks southeast of Tip Top house are in exactly the same positions as when photographed stereoscopially in 1869. Stability is the condition of the ubiquitious large block cover everywhere now.

Brouse around at any of the points of interest shown on the attached map.

Descend 200 feet vertically and 0.2 mile west on Crawford Path, you pass by the only vague glacial grooves and the sites where Hitchcock and others found the pink granite erratics in 1875 (1939, p. 12).

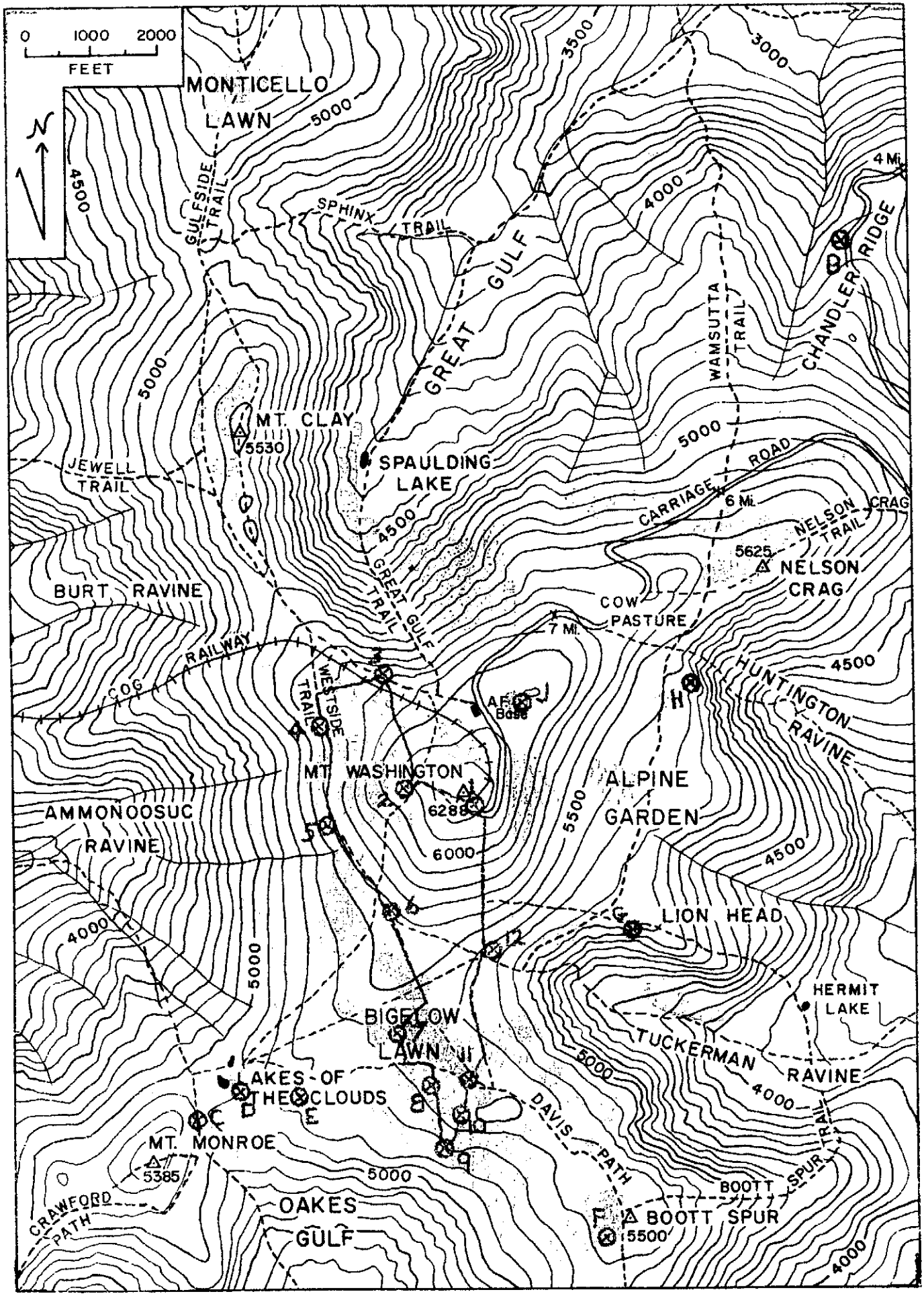
STOP 2. Crawford Path Corral at Gulfside Trail T-junction, 6100': Soils and solifluction.

A typical block lobe (tear-drop shape "sorted solifluction terrace"). These occur by the dozens but almost exclusively on northerly & westerly slopes of each cone (1939, p. 12,A). Tops are grassy, (sedge covered) at a 10° to 20° slope, but the lower bulge has boulder walls at 34°. These probably moved downslope in an active zone, first in one place then in another a few feet a year as in the Arctic today. Most but not all workers believe these and all other large sorted forms are stabilized today; this is based on (1) duplication of photographs of the 1870's and 1880's showing every piece in the same place (2) several 1 to 3 year duration steel tape measurements, (3) heavy vegetation cover of lichen on undisturbed topsides, well rooted sedge-tundra turf, and stunted spruce. Inclinometer studies are still being made. Only the upper 200 feet of Mt. Washington has permafrost today; it is sporadic and rare down to 5000' altitude. The new preprint (1971) discusses this.

Here also is the well developed Alpine Meadow soil especially under the little sedge covered flats. Alpine Turf (Retzer) are similar to Artic Brown (Tedrow). This dominates the grassy (Carex bigelowii) tops and centers of sorted patterns in wind-exposed areas above 4900'. It may be frozen to the surface now since it is frozen to a depth of 20" as late as mid July to mid August. Nearly 5" are black (5YR 2/1) organic coarse fibres and roots, decomposed in lower (02) part. One inch of black inorganic mixed fine sandy loam with weak fine platy structure is the A1 horizon. From 6" to 18" is dark reddish brown (5 YR 3/3 to 3/4) fine sandy loam B2h horizon. Roots are common. One place at least this lies (by solifluction) on 13 to 15" of buried A1 which is very dark grayish brown (19 YR 3/2). These both lie on brown (10YR 4/3 to 4/4) fine sandy loam C material. At many places the surface has crept downslope burying old organic surfaces, but these may be ancient.

On the gentle slope here Martin Cassidy (Harvard) had placed tubes measured with an inclinometer in 1964. Apparently these have not yet been remeasured although there is "move afoot" to do that this year. I have been unable to detect any motion (1971).

These forms on the steeper (11°) slope north, and toward the summit above, are crescents (gentle) or tear-drop lobes (steeper) which appear to be the steep-slope end product of a continuum of patterned soil. The basic sorting action produced a polygon net on slopes under 3°, but added solifluction makes these into stripes from 4 to 7°, and crescent-shaped sloping terraces near 10°. In tear-drop shaped lobes (1971) the average slope of the grassy tops in 56 lobes was 16°±4° and the average slope of the bouldery wall at the


0 1000 2000
FEET
N
MONTICELLO LAWN
5000
4500
GULFSIDE TRAIL
SPHINX TRAIL
3500
3000
4000
4 Mi.
CHANDLER RIDGE
WAMSUTTA TRAIL
GREAT GULF
MT. CLAY
5530
SPAULDING LAKE
JEWELL TRAIL
5000
CARRIAGE ROAD
6 Mi.
NELSON CRAG TRAIL
5625
NELSON CRAG
BURT RAVINE
COW PASTURE
7 Mi.
GREAT GULF TRAIL
COG RAILWAY
WESTSIDE TRAIL
A.F. Base
HUNTINGTON RAVINE
4500
MT. WASHINGTON
6288
ALPINE GARDEN
5500
AMMONOOSUC RAVINE
6000
LION HEAD
HERMIT LAKE
BIGELOW LAWN
TUCKERMAN RAVINE
LAKES OF THE CLOUDS
DAVIS PATH
MT. MONROE
5385
BOOTT SPUR TRAIL
CRAWFORD PATH
OAKES GULF
BOOTT SPUR
5500

leading downhill edge was 34° ± 8°.

Go right, north, 0.2 mi. on Gulfside Trail, to Great Gulf. As you approach the Cog Railroad note Lizzie Bourne monument far to the right. Pictures in 1968 show no change in boulders set in the grassy foreground or in blocks on slopes behind that monument since it was set up in the 1850's.

STOP 3. Sharp rim of Great Gulf, at 5750': local glaciers

This faces [illegible]N 14° E[illegible], was cut 1000' deep (1250' here) and the headwall averages 45° slope below us (1970, Table 1). This heads the longest of the local glaciers, 3 to 5 miles by 1500 feet wide, with two tributaries from the left and one (Madison Glacier) failing to meet it (seen at Stop B). Sphinx basin, (an incipient cirque) on the left, hangs into Great Gulf. Calculation by analogy places snowline (equilibrium line) at about 3000' and the terminus at near 2000' (the altitude of AMC Pinkham Hut).

The asymmetry of the trough below us may be due to (1) structure of dipslopes down the right-side or (2) abrasion of continental ice sheet later coming S40E from the left, or (3) greater cutting-undermining of west (left) side under Mt. Clay due to snow accululation from westerly winds.

The sharpness of this rim led Douglas Johnson to believe these cirques were made after continental glaciation (1970). With other evidence now present I believe it indicates completion as late as possible, say Early Wisconsin (Altonian) 50,000 or 30,000 years ago. Slopes below still do break off in rockfall occasionally. These are avalanche gullies keeping the rim sharp. There are 5 new avalanches in 30 years on the right (east) wall.

In Jefferson Ravine, far tributary on the left, are roche moutonées down the upper headwall (1970, Fig. 3). On the trough floor below here are many pink Olivarian granites carried from the valley on the other side of those Northern Peaks. On one bedrock ledge below Lake Spaulding is a groove probably glacial, which aims northwest-southeast across the valley All these (and more) indicate that continental glaciation came after all significant cirque cutting.

Treeline is at its lowest on Chandler Ridge (Auto Road, right) probably because winds are unusally high (believed strongest in World) there. Or it is less moisture and no snow protection, as others believe? Felsenmere is at its very lowest (3200') on the Adams Buttress, directly downvalley were the trough turns northeast. Does this mean permafrost got that low?

Walk west and southwest across the cog railroad 0.2 mi. to Westside Trail. Down the railroad, 600' vertically, is Jacob's Ladder where stereophotos 3C were taken in 1869 and repeated (3B) in 1938. (1940, Fig. 15,16). No change at all of position of boulders large of small is noted. The lichen side-up of rocks here indicates long (centuries) of non-disturbance.

STOP 4. Westside Trail at 5650': Erratics and date.

Here, as on the northwest slope of each peak, are numerous large rounded pink granites (Olivarian Magma Series) among the surface jumble of Littleton Mica Schist blocks (1939, p. 13). The erratics are found on ridges far

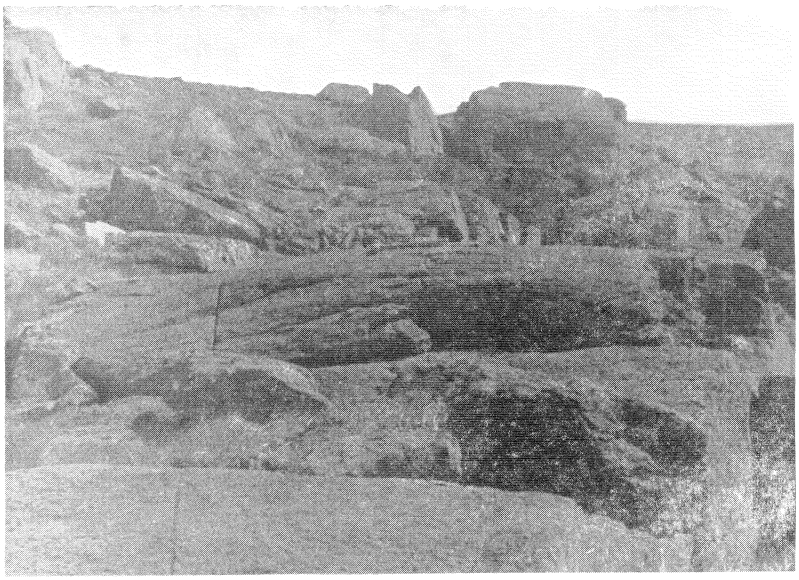


Figure 3A

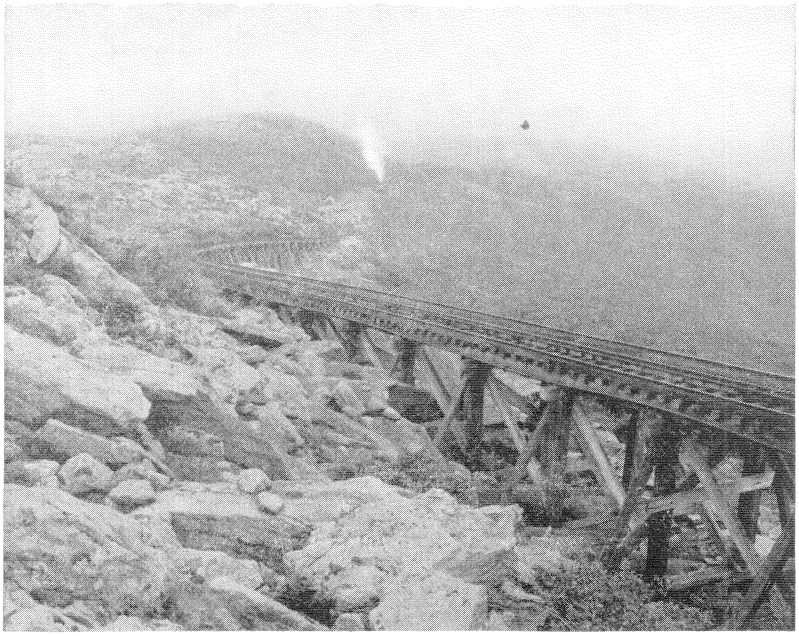


Figure 3B

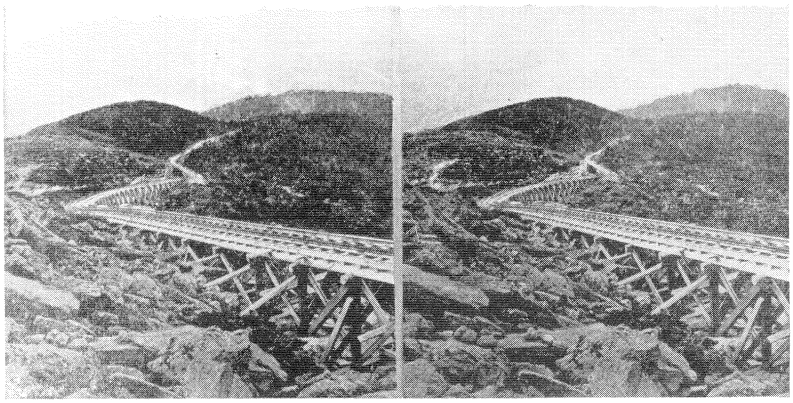


Figure 3C

east of here (Fig. 9, 1940) and in valleys like Pinkham Notch. These granites had to be raised 1400 to 3000 feet to get here from any known outcrops in the valley 4 to 8 miles to the northwest. Here they constitute less than 0.4 % but at the same level west of Mt. Jefferson they make up 11%.
Hard greenish black-white diorites are Lost Nation Group from 20 miles to the northwest. Weak salt-and-pepper binary granites, slightly yellowed are Bickford granites from Base Station below us, west, They rose most in ice (> 3200 ft.) and are more abundant ahead on Bigelow's Lawn. Why do these occur on the northwest slopes, and gentle uplands or valleys, even as far as Pinkham Notch, but none occur on the steep southeast side of any cone? Is there a dead ice "shadow zone"?

Weathering of boulders is one "iffy" way to determine the age of the highest glacial drift. As exposed here: 102 Olivarian (pink) granites averaged 2.6 mm rims.
72 Bickford (binary) granites " 2.9 mm rims.
46 Lost Nation (hard) diorites " 2.8 mm "
21 Albee (hard) quartzites " 1.8 mm "
This was deemed to be post-Wisconsin weathering since no weathering products occur around these boulders.

STOP 5. West Cone, lookout to the Southern Peaks (5600'): surfaces, nunatak stage.

Here we see the several physiographic erosion surfaces:
(1) The West edge of Bigelow's Lawn ahead (left) is part of the Presidential Upland. Lakes of the Clouds lies below ahead at its lower limit (5000'). Is this a modified Tertiary surface or altiplanation? If altiplanation is continuing now above-treeline (as Thompson says) where is the movement? Why is there no great accumulation of rock products below? and why is this slope we are on not near-flat? (2) Broad facetted ridge ends southwest of us (1940, Fig. 2), slope into broad basins on weaker rock, Bickford granite. (3) Sharp valleys (a ravine or canyon stage) cut back into the upper edges of these broad basins and into the rolling upland. The one below, Ammonoosuc Ravine, is one of many facing southwest. They widened today by debris avalanches, evident in the scars; and debris is removed in steep cobbly streambeds (1940, Fig 4). None of these held significant local glaciers although they are as high as the 11 good cirques. Snow which drifted eastward and northward off the upland slopes determined where cirques developed; prevailing winds were southwest then (1970, Fig. 8), west northwest now. (4) Lower peaks were rounded by continental Wisconsin ice. Mt. Monroe may be asymetrical due to the dip of gneissic beds (lower Littleton Formation) or to ice-abrasion of the northwest slope. Each col, like the one just left of Lakes-of-the-Clouds, is heavily glaciated and has good roche moutonée and grooves (Fig. 3A and 1940, Fig. 13).

This forms sharp contrast with the block-strewn slopes below us. John Rich thought this was so sharp it must signify a much longer "nunatak" exposure. He proposed that late Wisconsin ice wrapped only as high as 5300', and the cones were exposed to severe frostaction then. I rejected this (1) because the limit rises so high (5500') and so low 3200' we saw, (2) because it is in many places gradational, and (3) because weathering criteria discussed at Stops 1 and 4. (also 1939, 1970) say latest Wisconsin age ice went over the

peaks. Just above us on a 45% slope a conference of soils men in 1967 describe a congelifract soil 18" deep, akin to Artic Brown slope phase. Even here the lichen and soil maturity suggest long stability.

Continue south to main trail junction: Westside, Crawford, Lawncutoff, and Davis, past one huge pink Olivarian granite erratic.

STOP 6. Junction Davis X Crawford Paths at 5550': arctic soils, creep.

Four hundred feet southwest of this junction (5400') is a well developed soil profile which may be available: It has few stones but these increase with depth.

Horizon	Depth	Description
O1	2-0	Black (5YR 2/1) fibrous peat; stone-free; lower boundry clear and smooth; extremely acid.
A1	0-3	Very dark brown (7.5YR 3/2) fine sandy loam; moderate medium platy structure, very friable; plentiful roots; lower boundary clear and wavy; strongly acid.
B21	3-6	Very dark brown (10YR 3/2) fine sandy loam; moderate medium granular structure, very friable; plentiful roots; lower boundary gradual and irregular; very strongly acid.
A1b	6-10	Very dark brown (10YR 2/2) fine sandy loam; weak fine platy structure, plastic consistency; abundant roots; lower boundary clear and wavy; strongly acid.
B22	10-22	Dark brown (7.5YR 4/4) sandy loam; medium fine granular structure, moderately friable; plentiful roots; lower boundary gradual and wavy; strongly acid.
C	22-35	Dark yellowish-brown (10YR 4/4) loamy coarse sand, very micaceous; structureless, moderately friable; no roots present; strongly acid.

Two hundred feet east of this junction is one of a number of quartz boulder trains down the cone of Mt. Washington above us. Huge quartz boulders are all around here and a swarm of quartz veins is found in ledges 400' above us. Four such boulder fans, here and on Mt. Adams were noted by J. W. Goldthwait. Since they go directly downhill (20° slope), and this is perpendicular to well-established glacial movement, it was gravity movement. Quarrying by riving and downhill travel must have dominated the scene once. Was this 9000 to 14000 years ago? Continue 0.2 mi. east over Bigelow's Lawn on Davis Path noting upended toombstone-like slabs and patches of sorted polygons. One hundred feet east of our crossing of Tuckerman Crossover Path are some of the highest good glacial striae in this area (5500') showing that continental ice moved S41E. Bedrock is shallow everywhere. We leave the Davis trail southwest down the rut of the former old Crawford Bridle Path 0.1 mi. Horses hoofs from 1840, followed by erosion, made this deep, but boulders have edged into the center of the trench to block it now.

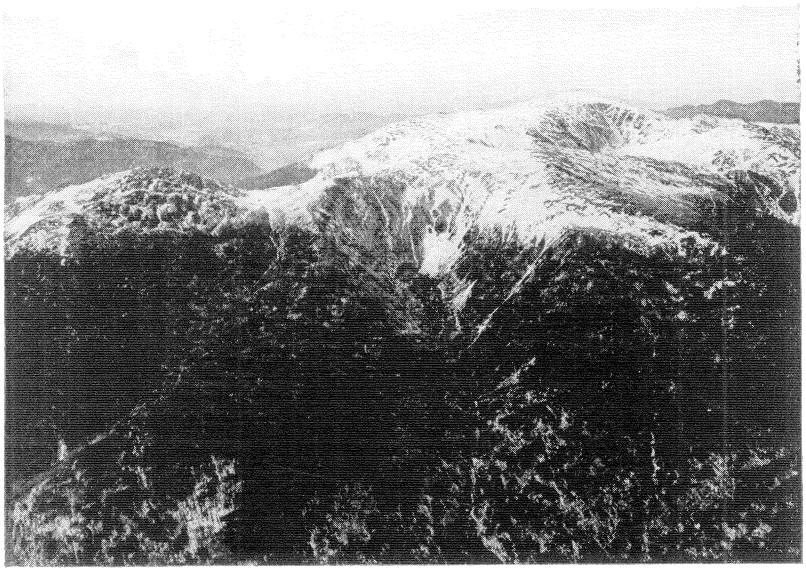


Figure 4A

Figure 4B

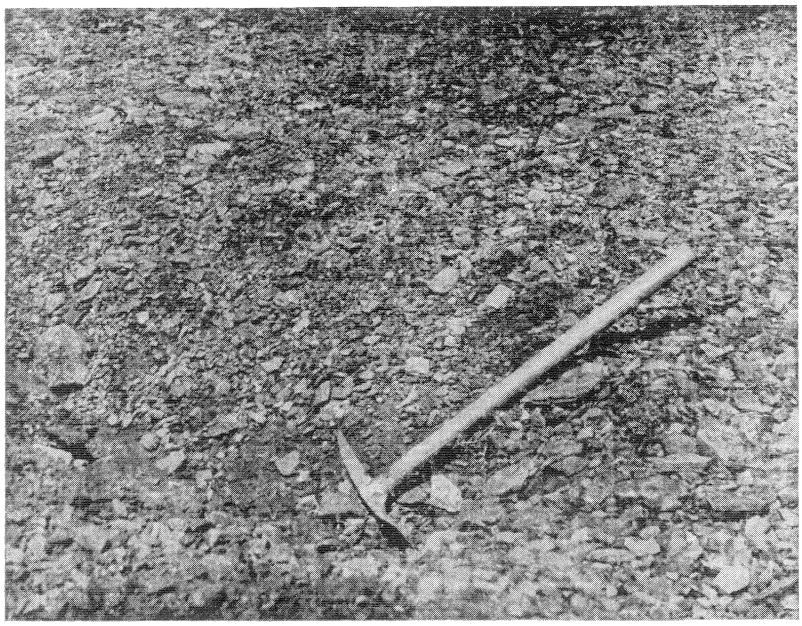


Figure 4C

SIDE TRIP C. Northeast of Mt. Monroe cone, 5100': turf-bank terraces. (Adds 1.5 mi. with D. and E.)

Under Crawford Path southeast of Lakes-of-the-Clouds are accumulations of sandy wash, and weathered gruss off Mt. Monroe. These are a series of 1' to 2' steps with risers of vegetation (Diapensia mostly) and active open tops (Fig. 1A). Activity, as at stop 7, is indicated by hardy arctic annuals like goldenrod, bluebell, and sandwort. Break-through streams of rock chips down risers here moved 7 marked brass tags 2" (average) downslope in 10 months. A trench (Fig. 1A) and probing revealed no permafrost here although the lowest patch of ground ice known was struck in August excavation for one part of Lakes-of-the-Clouds hut. Activity must be due to seasonal frost, which here is near a maximum (80 freezings per year, 1971).

SIDE TRIP D. Lakes-of-the-Clouds, 5100': rock glacier.

Here is a neat small glacier down a 25° trough slope between ledges and fanning-out at 11° slope into the highest of the lakes. See map. A very much broader tongue-like mass came down the head of Kings Ravine on a 38° bedding-dip slope and came to rest on the floor (now wooded) at 17° (1940, Fig. 8). Tape measurements from nails in the bed rock showed no motion of 20 marked boulder corners in 3 years.

SIDE TRIP E. Old Crawford Path east of Lakes-of-the-Clouds, 5230': roche moutonée.

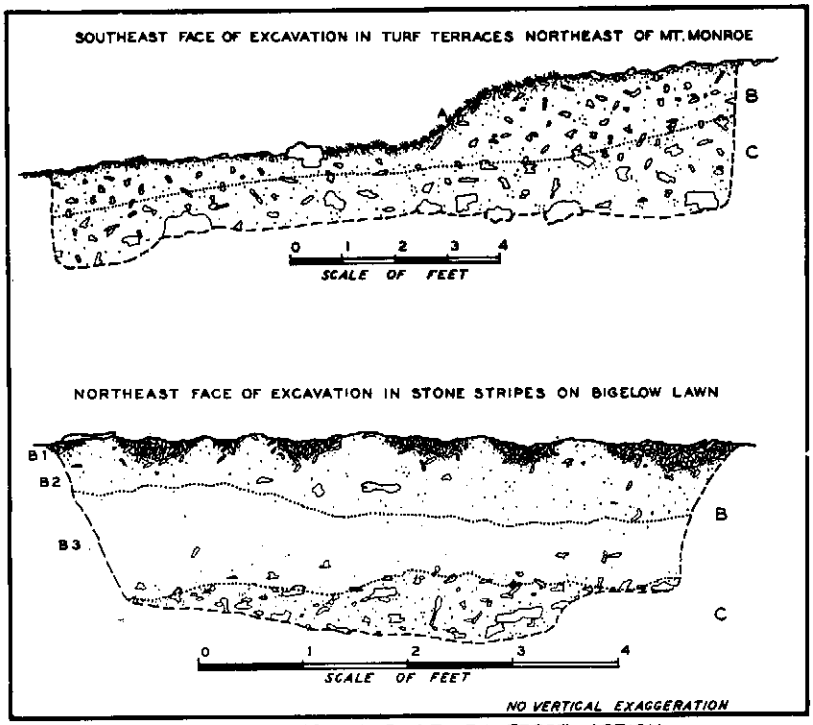
In the col here between Mr. Monroe and Bigelow Lawn (Mt. Washington) are much more abraded and better preserved signs of glacial erosion. Striae even suggest some funnelling (more miles of ice) between the peaks rather than over them. These roche moutonée aim S20°E. They have been split along a few NE-SW joints and blocks are now displaced a little by frost (Fig. 3A; also 1940, Fig. 13).

STOP 7. Open soil knobs on Old Crawford Path, 5320': frost sorting.

Here are miniature sorted patterned soils: nets on the crests with <5° slopes (Fig. 4B) stripes on slopes of 7°. Patterns are made by furrows of chips 1-8 cm long standing mostly on edge but only 3" deep and 6" to 12" apart. The material is very sandy at the top: 20% stones, 57% sand, 23% silt (and little clay) and these fit the diagram 1971, (Fig. 1) for the slope of such patterned features just as larger block forms do. Sorting is restricted to the upper 5- 8" but some weak soil horizons have developed (Fig. 1A, lower diagram). Sand may have accululated here by recent colluvial-alluvial wash from the old Crawford Bridle Path during the last century.

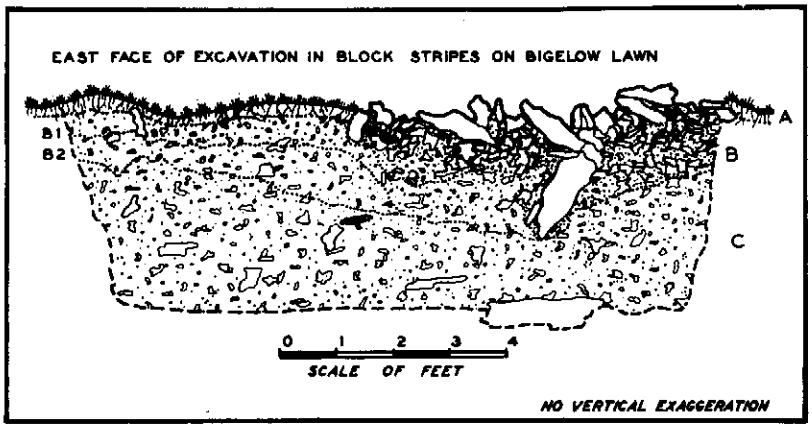
These patterns are actively forming. The area of Fig. 4B was raked over to be homogeneous in 1937 but it reformed, weakly in one year, fully in two years. Hotel key tags with numbers were set among the slaty chips and measured from fixed boulders by tape. 29 tags moved 0.83" avg. or 2.38" maximum down slope. Eight had changed strike-dip completely. Frozen ground was 9 to 24" deep on 5/16/37 under juicy active zone. A ditch dug in 1936 (profile Fig. 1A) was well filled in in 1937 and invisible by 1938.

The only plants successful on these fertile areas are arctic annuals such as



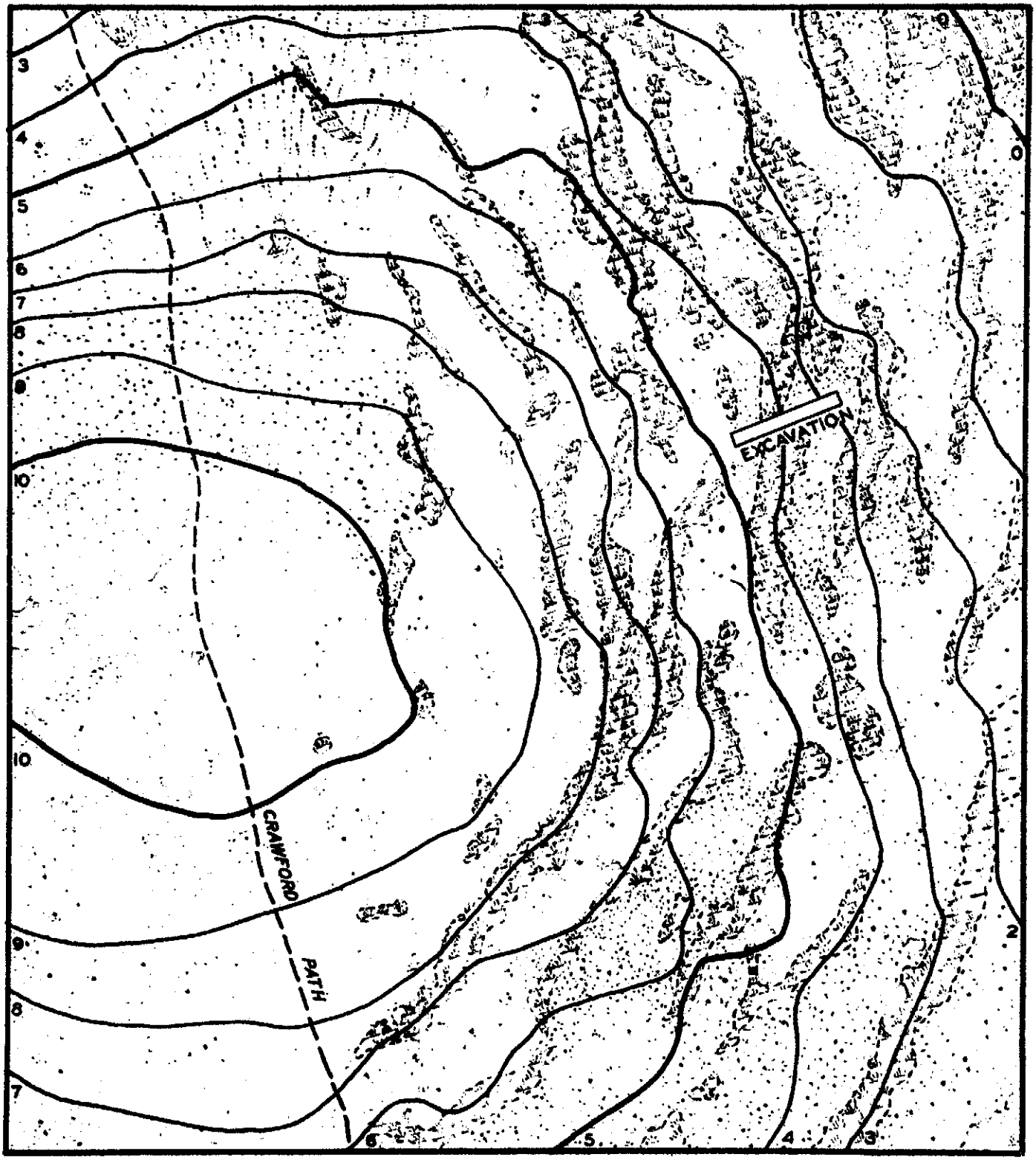
SECTIONS OF MINIATURE FORMS BUILT BY FROST ACTION

Figure 1A



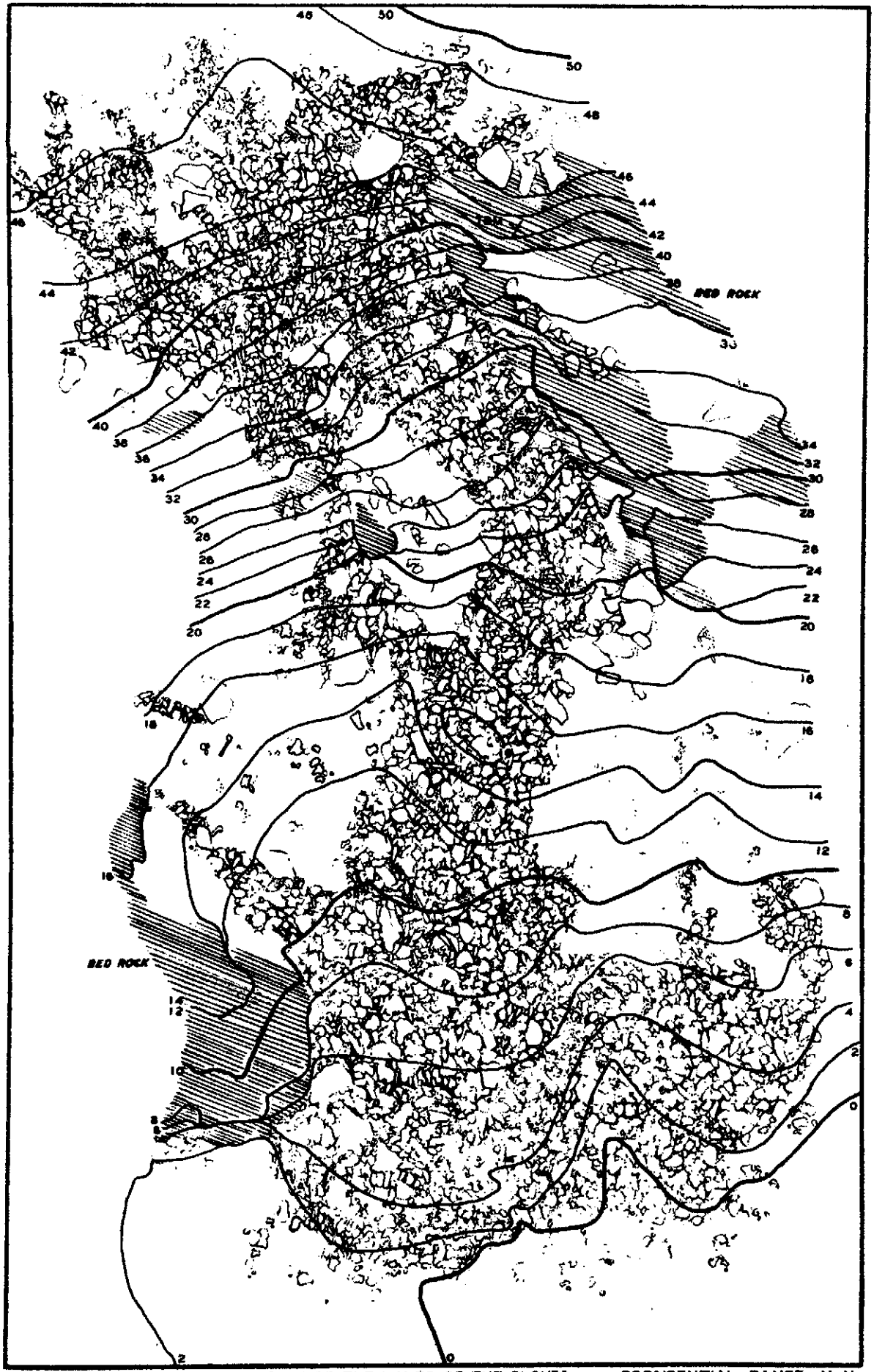
SECTION OF LARGE FORM BUILT BY FROST ACTION

Figure 1B



MAP OF TURF TERRACES NORTHEAST OF MT. MONROE, PRESIDENTIAL RANGE, N.H.

R. P. GOLDTHWAIT
J. NUTTER
1936



MAP OF BLOCK GLACIER NORTHEAST OF THE LAKES OF THE CLOUDS PRESIDENTIAL RANGE, N. H.

TRUE NORTH

0 10 20 30 40

SCALE OF FEET

CONTOUR INTERVAL TWO FEET

ELEVATION APPROXIMATELY 5300 FEET

R.P. GOLDTHWAIT
K.D. GOLDTHWAIT
1937

goldenrod (Solidage macrophylla), bluebells (Campernula rotendifilia) and sandwort (Ananaria groenlandica). More stable outer edges have willow (Salix uva-ursi) or diapensia (Diapensia lapponica). In the wet heaths below grow such things as arctic cottongrass.

Go cross-lots south to Camel Path 0.1 mi. Near here Kaye Everett and others (?) painted straight lines across rows of blocks in 1965. Many pieces are now moved out of place but there is real question how much this is due to trail disturbance. In any case boulder-clad solifluction lobes at the long edge of a solifluction terrace ahead (east) are stable; the highest krummholz trees grow with rings of 50 to 100 years suggesting stability. Trees may concentrate high up here because of snowdrift protection from wind and long-lasting moisture. Continue 0.1 mi. east and off path right.

STOP 8. SW slope of Bigelow Lawn at 5420': sorted stripes, stability.

Patterned soil stripes are turf-clad high soil centers 5' to 15' apart between boulder gutters made of tabular schist blocks up to 2 to 4' long and often on edge (Fig. 18 and map p. 35, 1940). Material at depth was clearly till: 27% stones (over 2 mm) 49% sand, 24% silt and clay. Across one grassy center and bouldery gutter a 3-foot ditch in 1936 showed the boulder concentration to 2 1/2' depth with smaller stones sorted into the lower half (1940, Fig. 20). Were the fines washed out at this thaw period of the year? or are they simply drawn upward by frost expansion under turf centers while boulders are separated horizontally and squeezed together in gutters?

Upslope 100' eight marked blocks moved 0.69" downhill (average) in 32 years as measured by tape (1971). In many probings no permafrost was found late in the season. It is proposed that these were really active and reached stability many centuries ago when permafrost was active.

These block stripes are on a 6° slope; on 4° to 5° slope above, just east, the forms are elliptical "cigar-shaped" stretched polygons, and at stop 11 above they grade to net-polygons on 0 to 3 1/2° slope. Clearly this is a continuum of forms indigenous to ground moraine in permafrost areas and varying by degrees of slope due to creep-solifluction. This relation is expressed on a diagram (1971) showing slope against percent of fines (silt-clay)which really express water retention.

STOP 9. Cairn over-looking Oakes Gulf, 5250': small local glacier.

A small local glacier, only half a mile long and one quarter wide produced a headwall 500' high, at slope angle 28°, above a 6° floor. Very similar situation existed in the next valley west dubbed "Monroe Basin". On the headwall of this Oakes Gulf, far to the right, are faint grooves diagonally across a schist outcrop at S9°E; this is part of the evidence (but not the best) that continental glaciers followed all significant enlargement of these valleys by local glaciers. There is no sign at all of U-shape or local facetting far down Dry River. Thus former snowline on the glacier (and equilibrium line) is calculated at 4000' to 4200' on the south-facing (S5°E) glaciers, (1000' below us). Contrast this with former short north-facing glaciers (Bumpus Basin, King Ravine) where similarly calculated snowline was 2900' to 3100'. Evidently the north-south insulation effect was at least 1000' of altitude or 4°F (2 1/2C). It should be noted too that these must have been the lowest altitudes at which glaciers could exist from drifting snow. These were critical threshold altitudes for glaciers (in Illinoian? Altonian?).

See the diagrammatic comparison (Climatic implications, 1971) which suggests that mean summer temperatures were 18°F (10°C) lower in the days of these glaciers (Early Wisconsin-Altonian?).

Go obliquely north, uphill 0.1 mi., to the nearest bedrock prominence.

STOP 10. West end of Boott Spur , 5460': frost riven ledge.

Some of these blocks fit together and fit back onto the bedrock ledge. Below and west several excavations showed that schist blocks are almost exclusively a surface phenomenon on top of till (Stop 8). Clearly these local boulders were hewn in a period of intense frost action and moved onto and over the till surface.

This regrigeration was not so intense as that producing mountain glaciers: 1000' to 1200' lowering, or 5°F (3°C) in annual temperature. Certainly this permafrost event post dates the Wisconsin ice deliver y of till; the hypothesis favored here is late Wisconsin beginning with the nunatak stage (13,000 to 14,000 years ago?). See 1939 p. 18.

These blocks have moved hardly at all in a third of a century. From a nail placed firmly in a joint in the most solid rock the marked sharp points of 10 blocks were measured by tape to a repeatable accuracy of ±0.25". These were remeasured after one year (1937) and 32 years (1968) with the loss of two points (by obscuring, loss of paint). Average total motion was 0.45" downhill with maximum measured displacement of 1.0" and only one in the eight moving uphill. This rate and degree of activity can hardly explain all we see. Nor will the large patterned nets (next stop) etc. form without permafrost which is lacking today.

Go 500' north over more rounded variety of Littleton Formation to the junction of Camel and Davis Paths.

SIDE TRIP F. East end Boott Spur, south side, 5450': stripes (Add 1.4 extra miles)

The diopside granulite member in the middle of Littleton Formation (a Devonian limestone) crosses Boott Spur north-south forming a rib-like ridge dipping 29° west (Fig. 2). From this, and similar small cliff-making units, flowed chips and larger rocks in great abundance when groundfrost was most active. Large blocks (11) remeasured by tape a year after marking, had moved 0.02" uphill, i.e. not at all, since this was within the limit of accuracy and no remeasurement showed more than 0.25". There was abundant evidence from lack of lichen that some of the small chips which made up the center did move, but no brass tags were used. In May 1937 seasonal ground ice was $8\frac{1}{2}$" to $11\frac{1}{2}$" deep in these forms.
From the broad rounded divide at the crest with slopes of 0° to 4° where patterned nets formed there is nice sequence to crescentic terraces and lobes on 12° slope (and a lobe top at 14°) down which Davis Path descends.

STOP 11. Junction Camel and Davis Paths at 5460': large polygonal nets.

This area shown by detailed map (1971) shows 13 points (4 now lost) with slightly larger motions (average 0.66") in a third of a centory. Gravity (solifluction) is not a factor for the area is flat. Motions w ere in

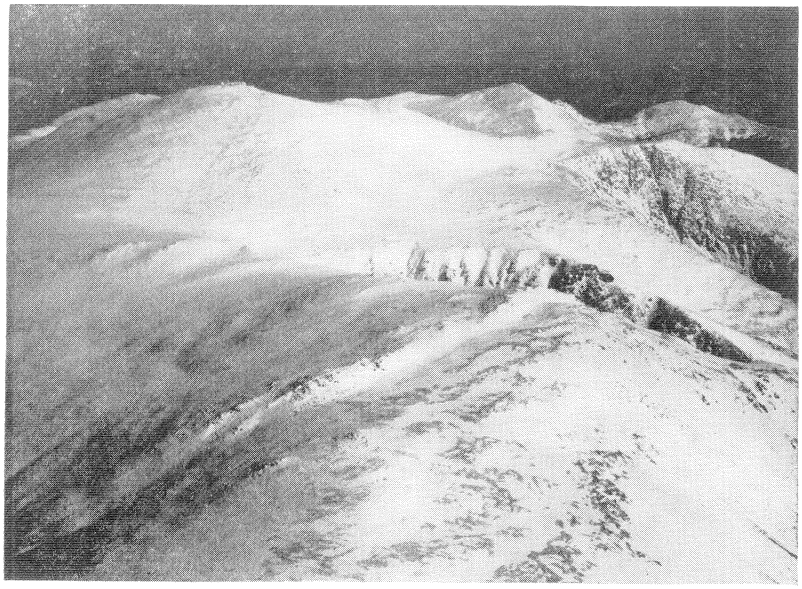


Figure 2A

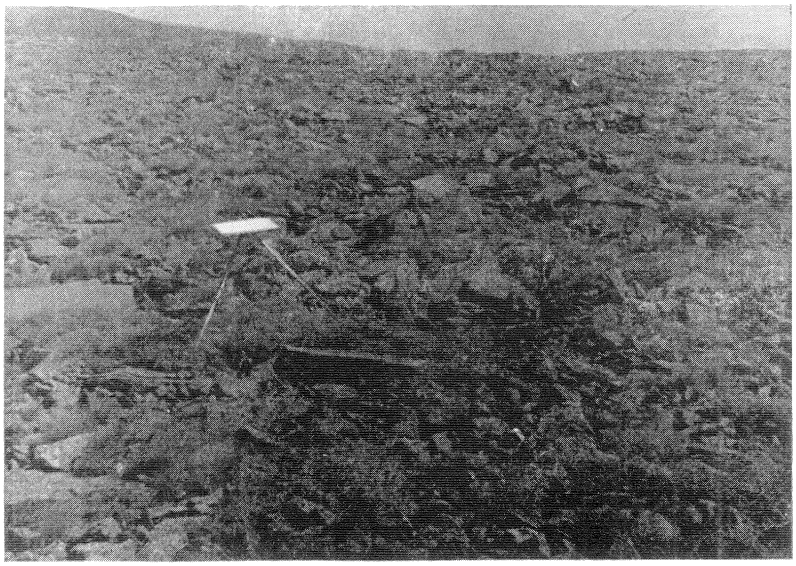


Figure 2B

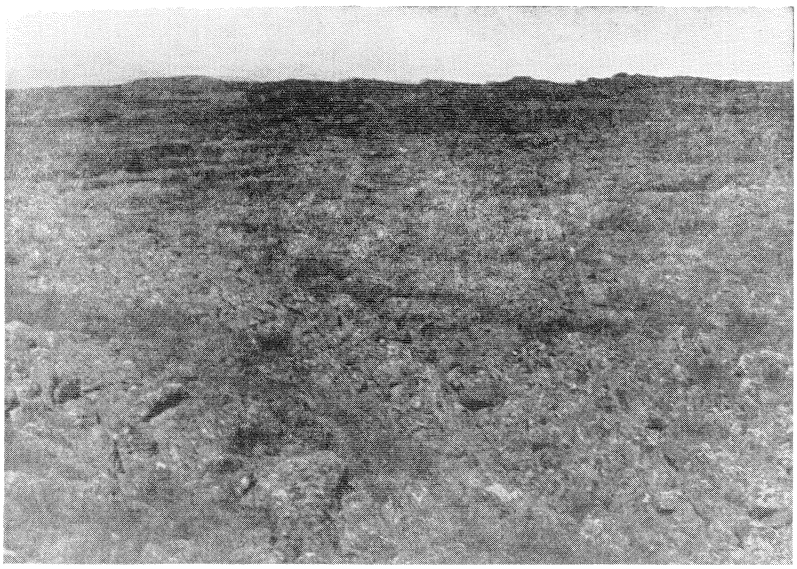


Figure 2C

several opposing directions. Base point nails were surveyed precisely from the bedrock knob just eastward, and did not move. Maximum motion was 1.63" and motion in the first year (12-points) averaged 0.13". Again I must conclude (from soils, lichens, old photography) that these are quiet and stable over the last century. Frozen ground was 5½" to 8½" deep in May 1937.
The grassy heath cover (Juncus trifidus) does not in itself deny any motion. But the turf is so thick in the polygon centers and soils are such a well devloped Arctic brown that rapid movements seem impossible.

A 0-2" Black (10YR 2/1) fibres and roots to very dark grayish
or 2 brown (10YR 3/2) sand loam. pH 5.0
B 2-15" Dark yellowish brown (10YR 4/4) fine sandy loam, weak granular structure, very friable, few stones, pH 5.5. Resembles or is two-storied, soil often and to 20"
C 15-22"Olive brown (2.5YR 4/4) fine sandy loam, silt and clay are 12 to 30% and moisture retention is high.

Go cross-lots northeast to Lawn Cut-off Trail and north on it 0.5 mi. to trail junctions.

STOP 12. Tuckerman Junction, Lawn Cut-off, Tuckerman and Crossover Trails, 5360': striae, local glacier.

The resistant diopside granulite called Boott Member of Littleton Formation outcrops on Little Headwall below and at high points on the end of Boott Spur (right) and Lions Head (left). Can the rolling Presidential Upland (Fig. 2A or 1970 Fig. 6), with 1000' of relief and contrasting with sharp glacial- and stream-cut ravines below, be explained just as erosion on hard-soft metamorphosed beds? or was that long Tertiary (?) erosion one of altitudinal and vegetational control (i.e. altiplanation) as well? or are repeated (3x) lowering base levels and cycles of erosion necessary? This is accordant with Carter Range eastward, Mt. Carrigan etc. on sloping plane southward, and the amazing Tableland top of Mt. Katahdin 180 miles northeast.

Grooves and striae, S67°E, obliquely across the foliation, under the cairn here are clear evidence for the continental (Wisconsin?) glaciation. It is further east than average because this is in the lee of Mt. Washington's cone and ice flowed around in part; once again more ice went over the cols and lawns. It funnelled down into already-formed cirques because converging grooves (S50°E) occur on Lions Head (left and 1940, Fig. 12), below us all the way right (S67°E± 5°) across Tuckerman Rim, and above us along Tuckerman Crossover and on Southside Trail to stop 6.

Tuckermans is the most spectacular of the cirques and a paradise for skiers until this time in spring. No wonder it holds drifted snow up to 50' deep, when you see the broad windswept upland (south) from which those 203" of mean annual snowfall can gather. Signs of ice facetting and U-valley to Crystal Cascades (2200') the former glacier went nearly 2 miles below the lower headwall right. The suggested former snowline is 3100' on the ice, (1970;reconstruction, 1939, p. 17). Summers were 17° or 18°F cooler then. It is clear that these cirques were all the critical lower threshold for permanent ice because of altitude sensitivity to insolation (1970, Fig. 8).

The bowl-shaped upper headwall (1970, Fig. 2; 1940, Fig. 10; 1939, p. 14) out-of-sight below you is 600' deep from rim to floor at average slope 38°; and 1000' wide. The floor is a broad U-shape which hangs 300' at Little Headwall into lower Tuckermans. It's avalanche-scarred headwall to the right is 1100' deep at 36°. Hermit Lake lies in the lower bowl. Debris avalanche came down Lions Head face (left) after heavy rains like Nov. 1927 or March 1936.

In spite of the sharp rims, moted by Douglas Johnson, but sharpened by rock avalanche, I believe all significant cirque cutting here came before continental glaciation. Reasons here are, first, the excellent striae on knobs on the headwall below us from the rim (S67°E ±5°) to the arch (S54°, 1970, Fig. 5; 1940, Fig. 11; 1939, p. 15) and south of it (S27°E±15°) on smoothed bedrock and slopes dipping 8° to 36°SE. These are argued by Thompson and others as the product of avalanches or creeping snow. Second are the erratics, especially Olivarian granites from over the mountain crest, making as much as 5% of the drift in streambeds in Tuckermans. Third is the absence of detectable or sensible end moraine systems. Some argue that the ridge on the left of the trough below (1970, Fig 4) are lateral moraines, but the slope between it and bumpy material to the right is far too narrow for a glacier. The ridge hooks into the cliff below Lions Head and in all ways resembles talus rampart and push ridges below small Alaskan rock glaciers (1970). Nothing but occasional bedrock-controlled hummocky drift (e.g. holding Hermit Lake) could be found (airphotos or walking) all the way down toward Pinkham Notch, or below any other U-trough.

The little basin just at our feet may be a nivation basin--once full of snow all year. It is wet all year and exhibits Alpine Meadow soils poorly drained even on 20° slopes:

A	0-8"	black (10YR 2/2) silty loam pH 5.0, organic rich.
A_3	8-11"	dark brown (10YR 3/2)silt loam, pH 5.1.
C	11-22"	dark brown (10 YR 1/2, 4/3) coarse sand, pebbly, pH 4.5.

Ascend the cone of Mt. Washington 920' vertically up Tuckerman Trail, north, 0.5 mi. Near Lions Head Trail T junction note high poor grooves S34°E. Look back at Bigelow Lawn next to Boott Spur to see the beautiful patterns of nets at the top and stripes marking the curving downslope lines northeast. Note the lack of glacial erratics on this trail; it is in the "shadow zone" of Mt. Washington. Why?

SIDETRIP G. Lions Head Trail lookout to Tuckerman Headwall, 5100': cirque, rampart. (Adds 0.7 mi.)

This affords a much closer view of the upper cirque headwall, the snowdrifts (arch) covered with skiers, and the rampart ridges below developed by pushup and flow from either side-wall. I believe the freshness of this cirque argues for completion no earlier than early Wisconsin (Altonian) time. Tuckerman Trail (under the snow, below, right) ascends along a ledge formed at a (Triassic?) dike. Grooves on the end of this ridge left S50°E (dip 36°) and all across the headwall (right) attest to over-riding continental ice.

Right behind you on Alpine Garden there are few or no erratics. This edge is in the "shadow zone" of the cone of Mt. Washington. The surface is Presidential Upland, and it is now covered with alpine wet meadows. These are mostly eastern arctic (Laborador and Greenland) species.

Soils on a 7° slope here in a well drained spot under krumholz black spruce

and Vaccinium cover are described as :

F/H	0-10"	Humus, plastic-sticky (5YR 2/1), amorphous sharp base.
A2	10-13"	Light gray (5YR 6/1) loamy fine sand, friable.
A2	13-27"	Brown (7.5YR 5/2) gravelly loam sand.
Bh	27-33"	Dark reddish brown (5YR 3/3) gravelly loamy sand.

SIDETRIP H. Rim of Huntington Ravine, 5300': deep cirque (Adds 1.8 mi.)

This valley joins Tuckerman Ravine below and is a twin cirque. In between is a hanging nivation basin, Raymond Cascades. It's steep 1000' craggy Huntington headwall below is a challenge to rock climbers. Average slope is only 40°, however, and the U-trough (1940, Fig. 7) is 900' wide. The U-valley below ends well above Pinkham Notch where you stayed last night (1939, p. 17). The mountain glacier ended just above that camp (prior to continental glaciation).

Across the trail you will see turf-banked (unsorted) terraces with 2 to 6 foot high risers or steps. The turf plant is mostly Diapensia.

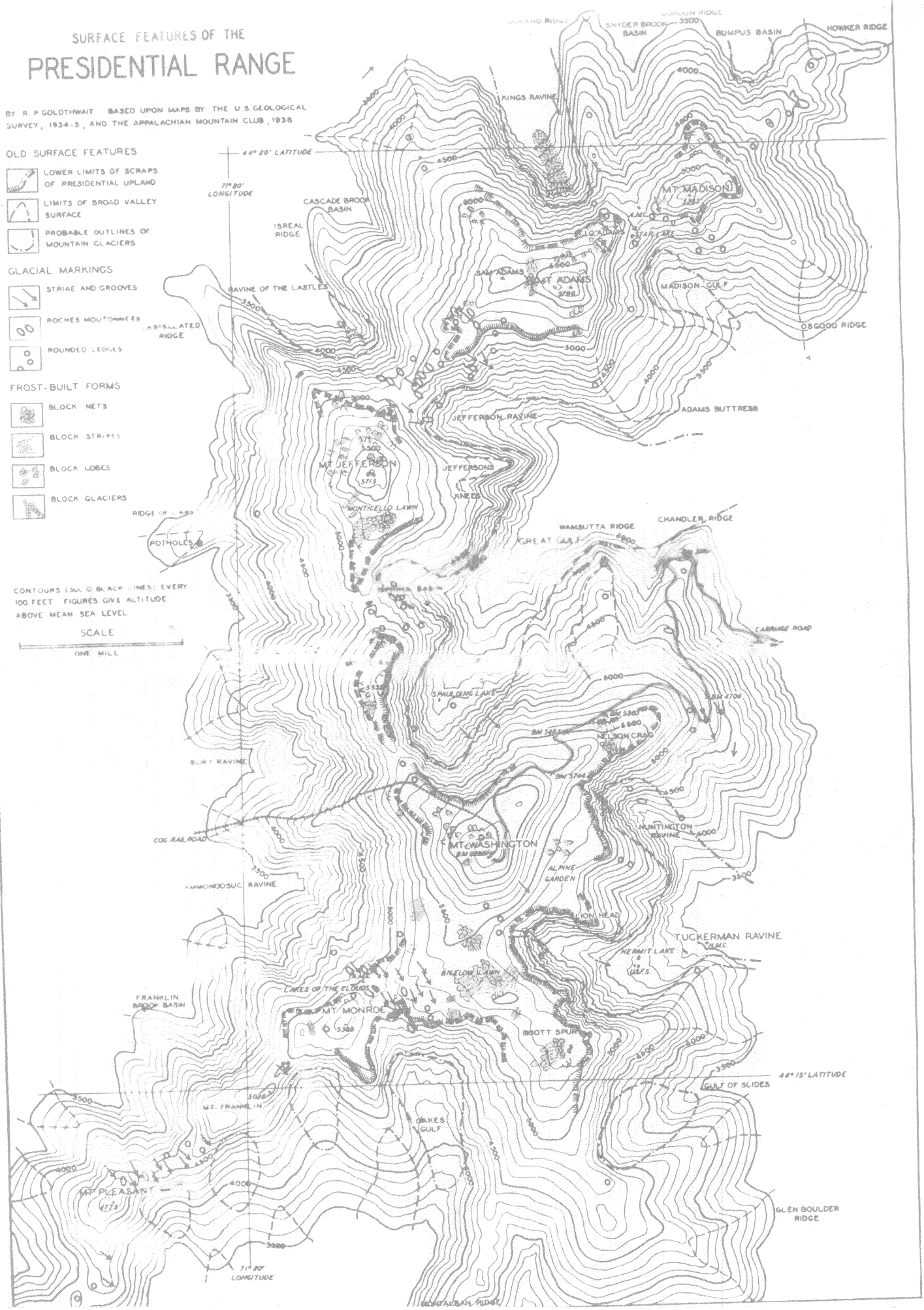
Follow north northwest up the Huntington Trail, 300' over a saddle 0.3 mi. to the Auto Road.

WALK 1. Main Auto Road Pit, 1 Mile Post, 2100': mountain kame.
(off load from descent vehicle.to see stop, walk remainder down)

The auto road is maintained from gravel, and from sandy till, all deformed together in typical hillside kames. Large blocks and till masses attest to ice contact situation; the topographic expression is not sharp and these are hard to discover. Deformed bedding shows the slump and collapse from ice walls and buried ice. Dips in several directions, seen over the years in bedding, suggest water from several sources on a down-wasting late ice mass. These get smaller and smaller upward to 4000' and absent or undiscovered above that.

SURFACE FEATURES OF THE PRESIDENTIAL RANGE

BY R. P. GOLDTHWAIT BASED UPON MAPS BY THE U.S. GEOLOGICAL SURVEY, 1934-5, AND THE APPALACHIAN MOUNTAIN CLUB, 1938



FRIENDS OF THE PLEISTOCENE

33rd Annual Reunion, 1970

May 23 or 24, 1970.

Potential stops (13 to 18) on highways counterclockwise around the Presidential Range (Mt. Washirgton) N. H.: Routes N.H. 16, Dolly Copp Road, U.S. 2, N.H. 302. Lettered stops J to N are possible extras to do when you can; or, for our use on the afternoon of Sat. May 23 if that day is impossible on top of Mt. Washington (Part I).

START 13. Pinkham Notch, AMC Camp, at 2020': fan, divide.

The camp where yo live is situated on a mile-long fan seen in creekbeds to have very coarse gravel and a steep slope of feet per 100 (°) at the western apex under Tuckerman Trail and Crystal Cascades. Here at the distil edge it slopes only feet per 100 (°) and is largely sandy. Distributary channels through the woods show clearly that its natural flow (Cutler Brook) was sometimes to the north (Peabody River) and most times to the south (Glen Ellis River) at this divide area.

Debris avalanches have reached this valley (Highway 16) from the spurs opposite and to the south (Glen Boulder) during double heavy storms (Nov. 1927) and spring melt storms (Mar. 1936). Where till is 5' to 15' thick on glaciated ledges over 30° this is a geologically common erosion process. The political term "landslide" was derived from Twin Mtn slide in just south of stop 17.

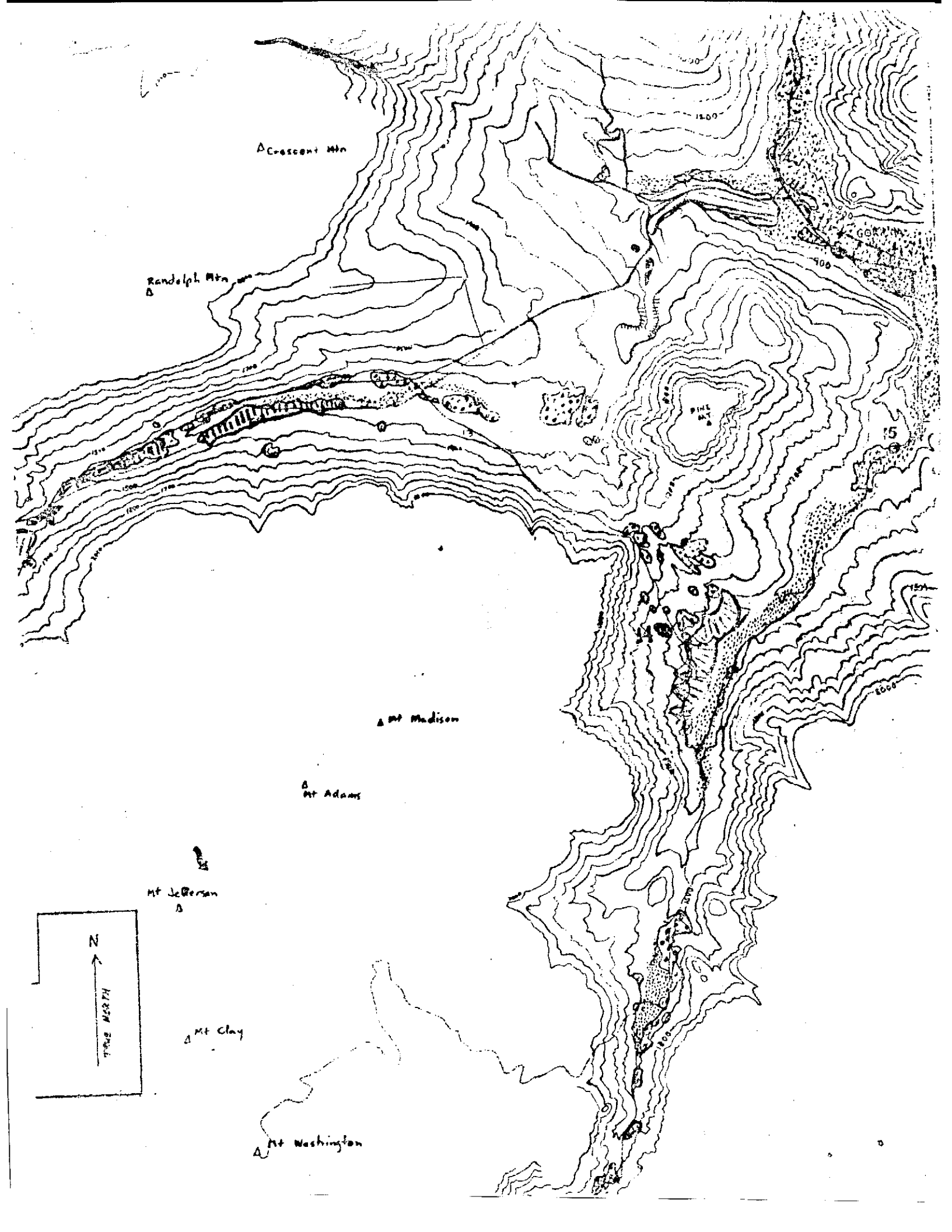
These two physiographic forms have been too-little emphasised as postglacial modifiers of the White Mountains. Even around low mountains 60 miles south (Wolfeboro-Winnepesaukee) I mapped extensive slightly finer medium gravel fans up to 5-mile-long lapping onto glacial kames with paleosols. No doubt the volume of such movements has decreased exponentially since the years of glacial downwastage and exposure, as is observed in Alaska today.

Around here 5% of the boulders in streams are Olivarian pink granites and Bickford binary granites from the valleys 1100' to 2000' high northwest of Presidential Range. It is unlikely that so many came around the mountains in lower ice, snake-dancing along valleys under the over-riding ice; the hypothesis preferred is that these lifted in ice over the cols at 4500' to 5500' and were excavated from tills deposited on this side.

Descend north 6 miles along Peabody River which is alternately on bedrock narrows carved into smooth pools, pot holes, and fluted grooves or a broad glen (floodplain @ 2.8 mi.) flanked by sandy kames. Turn left at Dolly Copp Camp (USFS) and up Dolly Copp Road 1.8 mi.

STOP 14. Dolly Copp Gravel Pit at 1580': kame deposits.

Highest kames found are near 4000' and just subdued lumps in the woods (exposed along Mt. Washington Auto Road). These are poorly sorted, or


Crescent Mtn
Randolph Mtn
Mt Madison
Mt Adams
Mt Jefferson
Mt Clay
Mt Washington
N
TRUE NORTH

bedded, and coarse. But as one descends they get bigger (WALK I on Auto Road) and better sorted. Slump structures, wrinkling and faulting-through-settling are common. Nearly all are north or west of some through valley watershed (Pinkham Notch) suggesting blocked drainage and down-wasing ice as prerequisites. Movement of waters was predominantly south or east, judged by structures and lithologies. These suggest that Ellis Valley deglaciated lowest first, then Peabody Valley then Moose Brook-Androscoggin, then Isreal River (stops 16,17) last

The source and level of these extensive kames (1300'-1600') indicate that the water came from Randloph and Jefferson areas to the west and over the Pine Mtn. col. Ice in Peabody Valley at a lower level than that in Moose Valley. Nevertheless ice thickness remained near 500' over the central valley.

Return to U.S. 16 and descend on late Wisconsin and post glacial river terraces northward almost to Gorham.

STOP 15. Peabody River Bridge, Route 16, Gorham (1 mi. S) at 935': tills.

For more than 40 years this high bank has been exposed; formerly without tree cover and freshly cut. Similar but lower banks on the NW side upstream expose extensive coarse terrace gravels and at least one high conical kame, akin to those west and higher to Stop 14.

Here one of the few exposed strattigraphic deposits showing something prior to the last advance of continental ice. Stony till up to 20' thick lies on laminated lacustrine clay and silt. What held this lake in? or where did it extend? These are unknown due to lack of other outcrops or well records. This lake may represent just the onset of last continental ice blocking Peabody Valley; or, it may be a lake of a previous stade. Pebbles indicate that the ice came from the north: a hard red granite common here outcrops to the north near Berlin, rather than west by Jefferson or Israel River. White Mountain Series rocks from Crescent Range are common. This could indicate a late resurgence of ice from the north, but certainly not a late ice cap movement from the highest peaks southwest. Whether this "lines up" with the isolated bits of evidence of readvance from the north cited to the west, such as Carroll kame-delta (Lougee; 20 miles), Bethlehem moraine (Crosby; 30 miles), or Fifteen Miles Falls till into varves (Lougee; 40 miles) is an interesting speculation, no more.

Go 1 mile into Gorham, joining Route 2, then west on it 12 miles to the fork, formerly called Bowman. The road follows two (Wisconsin) Androscoggin River terrace levels in the village and on a fan out of town east. As we leave Gorham up a long hill, there was once the finist exposure in New Hampshire of completely rotten Bickford Granite complete with rotten-soft pegmatite dikes. These were easily shovelled. A striated-grooved surface was covered with 4' to 12' till containing solid pieces of the same granite. This was interpreted as preglacial deep weathering preserved under fresh till (J.W. Goldthwait 1938).

Six miles out of Gorham, at Randolph, on the left and mostly carted away, is a large ice contact kame and esker field. A long sandy esker showed 9 1/2" of brown A zone and turf, 21" of dark orange red gravel B, and cobbly

yellowish C zone over 6' deep. The principal coarse gravelly fans with blocks are along the south side of the valley here or the north side as you get far west in Randolph. At old Bowman Station is a divide near 1500' which seems to have served as a channel, perhaps under thin ice at first.

STOP 16. BOWMAN CORNER road junction, 1500': kame terraces.

For a mile west from the Bowman bedrock threshold there is a series of sandy kames, with dipping structures, sometimes faulted and sometimes with limited flat tops. Lost Nation diorites and other western pebbles, as well as gentle gradient of uppermost kames, indicate eastward moving waters. This is a typical kame series for north- and west-facing valleys.

The highest extensive kames or esker-end with well sorted gravel is always near and just above the altitude of the bedrock threshold eastward or southwast out of the valley.

Israel river Valley eastward, 1720' (Stop 16), 1500' threshold
Peabody River Valley, southward, 2100' (Walk I) 2000' threshold
Ammonoosuc River Val.,southeast, 1900' (Extra stop B)

As in so many New England ice-contact situations deposition was insignificant until the waters hung-up on the inescapable threshold. Only the lower third of tenth of these deeper valleys bears such deposits then.

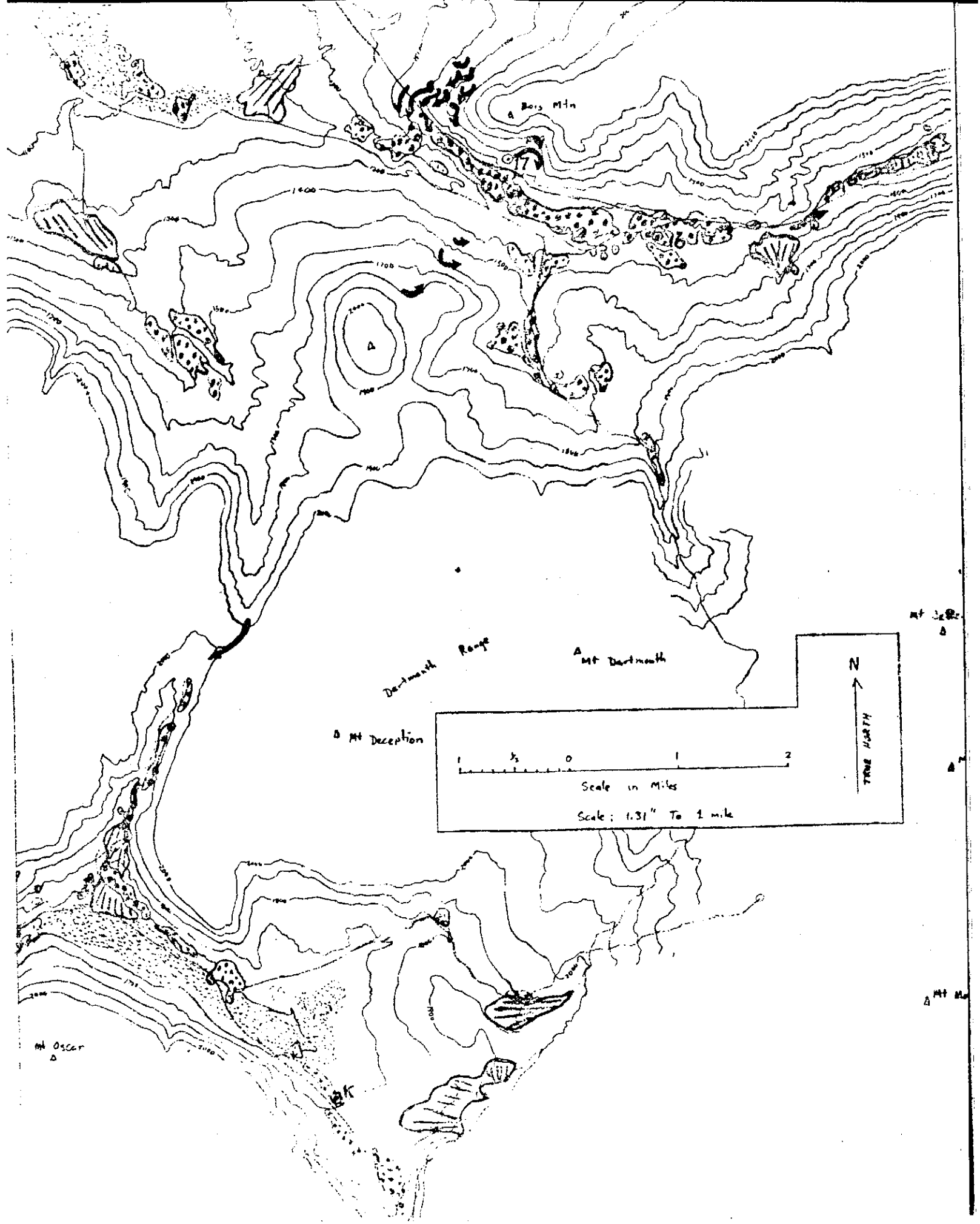
Above these kames by 10' to 100' and leading into them are "hillside" sublateral channels. It appears almost certain that the melt water, forced off the ice at 1800' and lower, cut into the till and deposited the channel products in these kames just below and to the east. To say that a certain kame was deposited from a particular channel is impossibleif we may judge from studies now going on in Alaska. From middle to late in each melt season waters become ponded at the mouth of such a channel to form a thin sandy step or entrance. The exit deposition is usually beneath thin ice.

Return to Route 2 and west 2.2 miles to farmyard.

STOP 17. BOY MTN. (W. Jefferson Highland) 1700': hildside channels.

This is an in-and-out type ice marginal channel as defined in north England. They run more or less along the contour instead of directly down slope. Each end is hanging, but is modified a little by drainagle down postgracially. The original channel gradient was eastward and southward over cobbles. So is the slope of 14 other channels on this south and west slope of Boy Mtn. (10' to 50' per mile S and SE) and the facing north slope of Hardwood Ridge. Surely this tells us that waters escaped eastward to Moose Valley (Bowman Threshold, Stop 16) and the wasting ice lay thicker later in Israel than in Moose-Androscoggin Valleys. This was the last broad basin to be freed of ice. Generally the cuts are 4' to 30' deep in till, but the wast end here left a pothole in bedrock, and one channel loop on Hardwood Ridge is all in bedrock. With cobble floors commonly 30' to 60' wide, it is believed by analogy this represents several hundred cubic feet per second of flow of early summer meltwater.

Alaskan studies (Burroughs Glacier; Michelson) also indicate that the slope of the channel is a rude indicator of the slope of the ice edge againist land. Many of the longer crooked one, like those crossed by the


Boris Mtn
Dartmouth Range
Mt Dartmouth
Mt Deception
Mt Oscar
1
½
0
1
2
Scale in Miles
Scale: 1.31" To 1 mile
N
TRUE NORTH

road west of here, do form indeed just beneath the thin ice, but as Rothlesberger showed in theoretical fashion (INQUA, 1969) there is a practical physical limit to depth of major water flow under an ice edge and therefore it flows laterally along it.

Does each of the 15 channels represent a year? In Alaska a suite of as many as 3 in-and-out channels was made in one year, but other longer sublateral channels sometimes have been occupied for two melt seasons. Certainly there were cut highest first (1775') and lowest last (1525') and if rates of cutting and lowering in similar topography in Alaska are analogous this whole group took 10 to 15 years to cut.

What happens to the melt water after ice gets too low to carry it to the threshold (here 1500')? Continuing west 1.8 mi., over other channels, and then left (south) on Route 115 down 250' in all to the basin floor, we find extensive low sandy terraces along Israel River from Highlands to Meadows (and NW and SW) and great masses of poorly sorted sandy till or sandy gravel bumps near 1200' and 1100' along the slope below Jefferson.

Still earlier water escaped from this basin southward, west of Hardwood Ridge. A col spillway at 2000' west of old Cherry Mountain Road leads south into Cherry Mountain esker (Extra Stop K).

EXTRA STOP J. Pit in Carroll at 1460': kame delta.

"Friends" stopped here with Lougee, many years ago. He conceived a delta (S to Twin Mtn.) with open lake west to steep ice edge.
Channels on Cherry Mtn. northwest.
Delta structure.
Ice contact boulders, till masses, kettles.
Irregular-non-lobate distil edge.
Follow Route 302 (east) left.

EXTRA STOP K. Pit next to Bretton Woods Golf Course, 1660': Cherry Mtn. esker.

Head 1940' along Deception Brook into 2000' spillway.
Center section kames, west of Fabyan, at 1600'.
Main ridges, multiple incidating collapse on ice (?), golf course.
Outlet end, 1890', Crawford Notch, to Saco Valley.
Movement southeastward: gradient overall, crossbedding, 21%±10 Olivarian.

If granite from northwest synchronous, ice 400' to 500' thick over, Annomosuc Basin (Fabyan) then. hydrostatic lower reach? or 200' melt-out let-down from ice?

Pebble counts:	North - - - - - - - - to - - - - - - Southeast					
Olivarian granite (Cherry Mtn.)	20%	23%	60%	56%	57%	56%
Lost Nation diorite (Starr King Range)	27	22	10	5	2	10
Mica schist and others (Presidentials or North)	7	1	6	3	2	2

EXTRA STOP L. View of Crawford Notch, 1800'.

Through-going U-shaped notches: continental ice
Depth of cutting 500' to 1500'.
Concentration of ice flow: striae funnelling in; 100x peak-col motion?
Why sharp top to Webster Cliffs (N) Willey Cliffs (S)? Late outlet glacier?
Site of Willey Slide 1841.

EXTRA STOP M. Willey House, NH state reservation, 1350'.

Willey Slide story.

EXTRA STOP N. Bartlett roadside, 710': perched boulder.

EXTRA STOP P. Jackson, Ellis River bank 1 mi. S, 760': two tills.

Fabrics (Fowler)

Return to Pinkham.