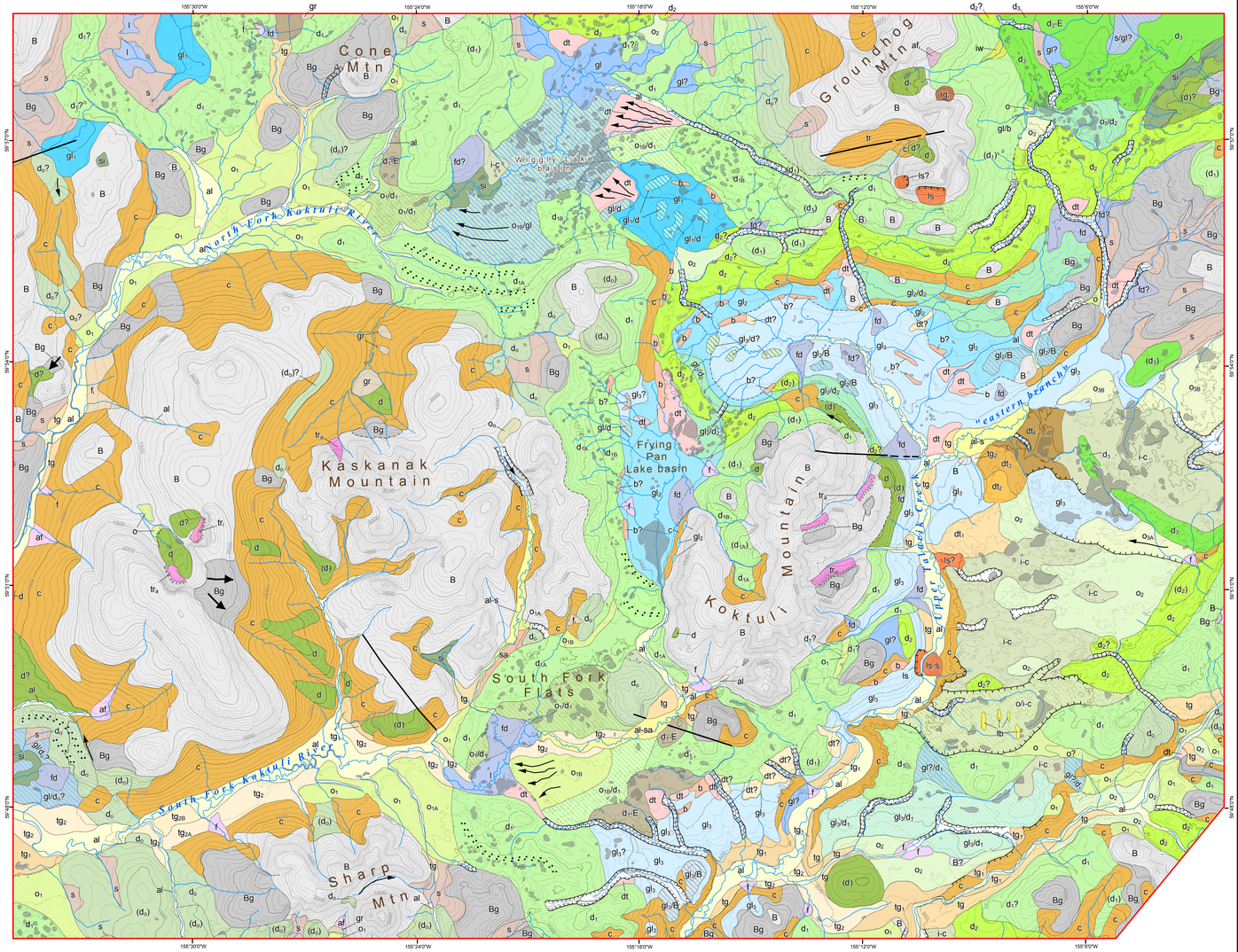


Surficial Geologic Map of the Pebble Limited Partnership's Pebble Project

By Thomas D. Hamilton

2007

THE pebble PARTNERSHIP

Miles: 0 0.5 1 2 3 4 5

Kilometers: 0 0.5 1 2 3 4 5 6 7 8 9 10

Contour Interval 50 feet

Alaska State Plane Zone 5 (units feet) 1983 North American Datum **Digital representation by M.R. Anderson, RDI**

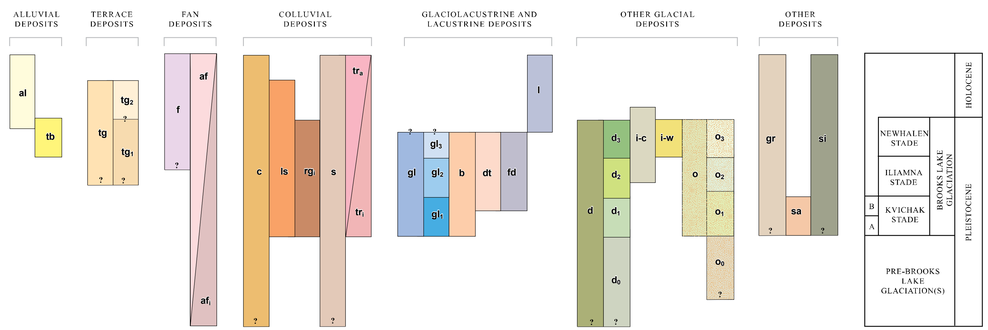
Digital files availiable at www.pebblepartnership.com

N

MAP SYMBOLS

- Direction of glacier flow across topographic divide
- Meltwater channel, showing flow direction
- Crest of morainal ridge
- Contact - dashed where approximately located or inferred
- Probably fault line (no offsets noted)
- Scarp
- Drainage channel - abandoned or containing underfit stream
- Lake

CORRELATION OF SURFICIAL MAP UNITS



DESCRIPTION OF MAP UNITS

[Map units shown with slashes, such as **gl/d**, indicate deposits of the first unit over known or inferred deposits of the second unit. Map units shown in parentheses, such as (**id**), indicate thin and generally discontinuous deposits. These overlie bedrock unless an underlying surficial deposit is specified. Units of either type are described below only where additional explanation is necessary. Units are queried where uncertain.]

BEDROCK SURFACE FORMS

B **Bedrock, undifferentiated**—May bear thin and discontinuous cover of rock rubble.

Bg **Bedrock, glaciated**—Bedrock smoothed and abraded by overriding glacier ice. Generally well exposed rock surfaces; commonly streamlined in direction of ice flow and channeled by glacial meltwater. Dispersed glacial erratic boulders and cobbles typically present.

ALLUVIUM

al **Alluvium, undivided**—Varies from moderately sorted, stratified, coarse gravel in upper valleys to muddy fine gravel or gravelly sand in depositional basins. Along smaller streams, unit includes fan, floodplain, and low terrace deposits that are too small to be designated separately.

Subunit **al-sa** designates alluvium in which sand dominates. Mapped only within South Fork Flats.

Subunit **al-s** designates alluvium in which silt dominates. Mapped only on east fork of Upper Talarik Creek and on stream that flows south into South Fork Flats.

tb **Transverse bars**—Alluvial gravel forming elongate deposits oriented normal to inferred former flow direction. Flanks facing downcurrent are steeper (20°-24°) than flanks facing upcurrent (14°-16°). Mapped only in broad west-trending outwash channel (map unit **o/i-c**) in southeast sector of map area.

TERRACE DEPOSITS

tg **Terrace gravel**—Alluvial gravel and sandy gravel, capped locally by floodplain deposits of silt, sand, or peat. Older terrace deposits commonly have thicker mantles of eolian silt or thaw-lake deposits.

Differentiated into **tg2** (highest and oldest terrace) and **tg1** (lower and younger terrace) where multiple terrace units present.

FAN DEPOSITS

f **Fan deposits**—Range from poorly sorted, weakly stratified, silty, sandy coarse gravel at mouths of mountain valleys to gravelly sand and silt within lowlands.

Subunit **fi** designates inactive fan deposits, as described above. These generally stand above modern stream levels, and commonly are graded to river terraces that rise above modern floodplains.

af **Deposits of steep alpine fans**—Coarse, very poorly sorted, angular to subrounded silty sandy gravel at mouths of avalanche chutes and steep canyons. Upper segments generally channeled, with levees of angular to subangular coarse debris. Lower segments commonly littered with similar coarse debris. Subject to snow avalanches during winter, shallows during spring snowmelt, and debris flows during heavy summer rainstorms. Surface gradients intermediate between talus cones and alluvial fans. Mapped only on west flank of Kaskanak Mountain block.

Subunit **afy** designates steep alpine fan, as described above, that appears no longer active. Mapped only on east flank of Groundhog Mountain.

COLLUVIAL DEPOSITS

c **Colluvium, undivided**—Widespread slope deposits consisting of rock rubble on upper slopes grading downslope into rock debris mixed with finer sediment. Frost creep may dominate on upper slope segments; solifluction on lower slopes.

ls **Landslide deposits**—Very poorly sorted, nonstratified, coarse to fine angular rubble, commonly with matrix of finer debris. Forms lobes below detachment scars and slide tracks on steep rock walls. Commonly formed by rapid downslope movement followed by period of relative stability, but may alternatively form by slow and progressive creep. Recognized only on southeast corner of Groundhog Mountain block and along east side of Upper Talarik Creek.

Subunit **ls-s** designates slump deposits (nearly intact blocks of rock or debris formed by sudden or progressive downslope movements, commonly with rotational component. Mapped only along west side of Upper Talarik Creek in southeast part of map area.

rg **Inactive rock-glacier deposit**—Very poorly sorted, nonstratified, coarse angular rock debris, with matrix of silt and fine rubble; formerly contained abundant interstitial ice. Frontal slope stable, gradually rounding back to upper surface. Mapped only near southeast corner of Groundhog Mountain block, where it forms lobate deposit at base of steep north-facing valley wall.

s **Solifluction deposits**—Slope deposits consisting of very poorly sorted, nonstratified to weakly stratified, stony silt and organic silt. Form smoothly graded, gently to moderately sloping sheets and aprons.

tr **Talus rubble, undivided**—Angular, unsorted rock debris, forming cones and aprons at bases of cirque headwalls and other steep bedrock slopes. Areas of active talus (unvegetated, unweathered to slightly weathered, with lichen cover sparse to absent) commonly are interspersed with vegetated talus that may have become stabilized following late Pleistocene (Brooks Lake) glaciation. Also forms thin and generally discontinuous sheets over many uplands mapped as "Bedrock".

Locally differentiated into **tra** (active talus) and **tri** (inactive talus), as described above, where these form sufficiently large mappable units.

GLACIOLACUSTRINE AND LACUSTRINE DEPOSITS

gl **Glacial-lake deposits, undifferentiated**—Stratified to weakly stratified silt, organic silt, and silty fine sand, commonly with dispersed dropstones. Grades into gravelly sand to sandy fine gravel near former stream mouths. Marked by smooth and poorly drained surface morphology, with sharp upper limit that coincides with beach and delta deposits (as described below). Mapped as compound unit (for example, **gl/d**) where drapes or overlies bedrock or other glacial deposits.

gl1 **Glacial-lake deposits, youngest**—Glacial-lake deposits, as described above, rising to altitudes of 800-850 ft above sea level (asl) along Upper Talarik Creek, and to about 900 ft asl along the Talarik's east and west forks. Postdate Iliamna-stade glaciation; persisted into Newhalen stade.

gl2 **Glacial-lake deposits, intermediate age**—as described above. Rise to altitudes of about 900 ft asl along Upper Talarik Creek near south margin of map and 1050 ft asl farther north along Upper Talarik Creek, in proposed Pit Area, and in basin north of Frying Pan Lake. Accompanied Iliamna-stade glaciation, and persisted during deglaciation.

gl3 **Glacial-lake deposits, oldest**—Glacial-lake deposits, as described above, rising to altitudes of about 1150 ft asl in Wiggly Lake area. A smaller remnant may also occur on northwest flank of basin that extends north from Frying Pan Lake. Accompanied Kvichak-stade glaciation, and persisted during deglaciation.

b **Beach deposits**—Moderately well sorted gravelly sand or sandy fine gravel. Forms ridges parallel to topographic contours along upper margins of glacial-lake deposits; their steepest flanks face lake basin. Wave-abraded platform with dispersed relict glacial boulders commonly lies beyond beach face, with platform and beach face meeting at sharp angle.

dt **Deltaic deposits**—Well sorted to very well sorted sand to sand with fine gravel. Form lobes with axes normal to topographic contours that extend across margins of former glacial-lake deposits. Where preserved, surface channels have digitate pattern. Generally border modern streams or abandoned meltwater channels. Queried where interpreted from aerial photographs but not field checked.

Subunits **dt1**, **dt2**, **dt3**, and **dt4** are successively lower deltaic deposits built into moraine-dammed lake near junction of east and west forks of Upper Talarik Creek as lake level progressively lowered from 880 to 770 ft asl.

fd **Fan-delta deposits**—Alluvial-fan deposits (as described in unit **f**) that grade downslope into deltaic and lacustrine facies (as described in units **dt** and **gl**). Generally have fan-shaped surface form, but distal (lower) segment is broader, more poorly drained, and more gently sloping than normal alluvial fan.

l **Lake deposits**—Silt and silty fine sand, stratified to weakly stratified. Probably of postglacial (Holocene) age. Mapped only on floor of South Fork Flats and near northwest corner of map area.

OTHER GLACIAL DEPOSITS

d **Drift, undifferentiated**—Unsorted to poorly sorted, generally nonstratified, compact till ranging in composition from muddy gravel to sandy coarse gravel. Contains local stratified ice-contact meltwater deposits consisting of moderately sorted sand and sandy gravel. Pebbles and small cobbles generally dominant, but faceted and striated stones up to boulder size are generally dispersed throughout deposit. Surface morphology commonly includes morainal ridges, dry and water-filled kettle depressions, conical to subdued mounds, and meltwater channels.

d3 **Drift of Brooks Lake glaciation, Iliamna stade**—Glacial deposits, as described above. Moraine crests irregular, but generally less sharp than those of Newhalen Stade. Forms large crescentic end moraine north of Frying Pan Lake basin that encloses proposed Pit Area and is traceable farther east along south and southeast flanks of Groundhog Mountain block. Other end moraines occur north of Wiggly Lake basin at north-central margin of map area and at southeast corner of map area.

d1 **Drift of Brooks Lake glaciation, Kvichak stade**—Glacial deposits, as described above. Moraine crests more subdued than those of younger Brooks Lake stades, and drift is more eroded on mountainsides. Form extensive end moraines that (1) cross North Fork Koktuli River near its head, (2) enclose South Fork Flats, and (3) extend west-southwest to Upper Talarik Creek in southeast sector of map area. A small portion of the massive Kvichak moraine around Iliamna Lake extends into extreme southwest corner of map area.

Subunits **d1A** (older) and **d1B** (younger) differentiated west and south of Frying Pan Lake and in Wiggly Lake area. The younger subunit, a recessional moraine, dams Frying Pan Lake.

Subunit **d1-E** designates area of Kvichak-Stade drift that have been eroded by an uncertain agent (either flowing meltwater or wave action along margin of glacial lake).

d0 **Drift of pre-Brooks Lake age**—Highly modified glacial deposits, generally remaining only as thin and discontinuous patches of drift on uplands beyond limits of younger glacial advances. A conspicuous moraine segment north of South Fork Koktuli River near southwest corner of map area was deposited by a glacier that expanded northward from Iliamna Lake area and dammed the South Fork. Drift and (or) outwash may also have dammed North Fork of Koktuli River at this time.

i-c **Ice-contact meltwater deposits**—Meltwater-washed sand and gravel deposited in contact with stagnating glaciers. Commonly forms conical to subdued mounds with well drained surfaces interspersed with dry and water-filled kettle depressions and abandoned meltwater channels.

iw **Inwash deposit**—Alluvial sand and gravel, commonly with interstratified silt, deposited where stream partly dammed against moraine flank. Mapped only on east flank of Groundhog Mountain at western edge of Newhalen stade drift (unit **d3**).

o **Outwash, undifferentiated**—Moderately well sorted and stratified sandy gravel forming broad aprons and elongate valley trains in front of moraines, and also terrace remnants farther downvalley. Largest stones decrease in size downvalley from large cobbles and very small boulders near moraine fronts to pebble-small cobble gravel in more distal locations.

o3 **Outwash associated with drift of Newhalen stade**—Gravel aprons and valley trains, as described above. Associated with moraines of Newhalen stade in northeast and east-central sectors of map area.

Subunits **o3A** and **o3B** differentiate outwash generated during maximum Newhalen advance (**o3A**) from recessional outwash that formed during glacier retreat (**o3B**).

o2 **Outwash associated with drift of Iliamna stade**—Valley train, as described above. Mapped only in southeast sector of map area, where broad terrace remnants extend west-southwest toward Upper Talarik Creek from end moraines near southeast corner of map.

o1 **Outwash associated with drift of Kvichak stade**—Extensive outwash aprons and valley trains, as described above. Mapped within and west of South Fork Flats and west of Wiggly Lake at head of North Fork drainage. Also associated with Kvichak moraine in extreme southwest corner of map area.

Subunits **o1A** (older) and **o1B** (younger) are differentiated only southwest of Frying Pan Lake and in South Fork Flats, where they are related to older and younger end moraines of Kvichak stade.

OTHER DEPOSITS

gr **Gravel, undifferentiated**—Isolated, gravelly erosion remnants of uncertain composition and origin. Mapped primarily in north-trending valley that bisects Koktuli Mountain block.

sa **Sand deposits, undifferentiated**—Well sorted fine to medium sand of uncertain origin near north margin of South Fork Flats.

si **Silt, ice-rich**—Poorly drained areas on lowlands that contain abundant small ponds interpreted as thaw lakes. Common on floors of lake basins in proposed Pit Area and north of Wiggly Lake, where they generally are not differentiated from glaciolacustrine deposits.