Evidence for late Wisconsinan outburst floods in the Tok-Tanacross basin, upper Tanana River valley, east-central Alaska

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ABSTRACT

The Tok-Tanacross basin is dominated by the Tok fan, which at the surface in the western half is Donnelly (marine oxygen-isotope stage 2) in age and is Holocene in the inset, eastern half. The Donnelly part of the Tok fan is primarily composed of massive, clast- and matrix-supported, pebble gravels with scattered small cobbles and interbedded medium to coarse pebbly sands. Gravels and pebbly sand beds are generally massive, ≤1 m thick, tabular with abrupt lower and upper contacts, and parallel the fan surface. In these coarse sediments, cross bedding is scarce, and lens-shaped channel fills of massive sand up to ~1 m thick are interlayered with the massive gravels.

Particularly instructive for understanding the development of the Tok fan during the last major glaciation is an exposure in the Donnelly fan remnant east of Tok River, where a 1.8-m diameter greenstone boulder was found in place near the top of clast-supported pebble gravel in the upper wall of a gravel pit. A nearby pile of extraordinarily large granite, quartz schist, greenstone, and basalt boulders demonstrates that at least six other large boulders were encountered during pit excavation. Exceptionally large boulders of similar rock types were also encountered in the Tok fan only at two other, nearby localities directly in line with the Tok River valley and were previously interpreted as evidence of penultimate glaciation in the Tok-Tanacross basin.

Lack of glacial till in the Donnelly portion of the Tok fan, the absence of cut-and-fill structures and ripples, scarce cross bedding, and channel fills of massive sand indicate that the extraordinarily large boulders and enclosing sediments were not deposited by glacial ice or typical water floods. We propose 1) that the western half of the Tok fan is a large expansion fan deposited by massive, pulsating sheetflows during outburst floods emanating northward from the Tok River valley and 2) that the extraordinarily large boulders were deposited as dropstones from icebergs and rapidly buried by hyperconcentrated flows during these periodic inundations. Evidence for outburst floods of Donnelly age was previously recognized in the upper Tok River valley by Schmoll (1984).

Key Words
Hyperconcentrated flows
Tok expansion fan
Donnelly Glaciation
Outburst Floods
Tanana River Valley

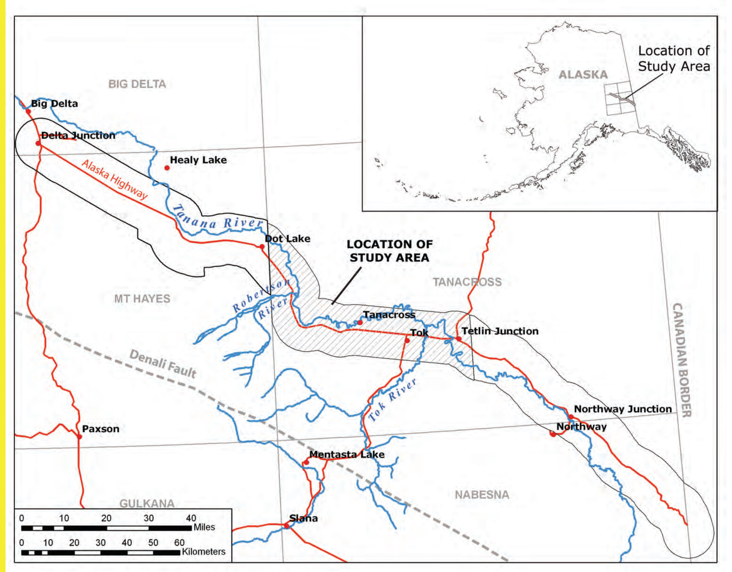

Figure 1. Location of study area in Tanacross Quadrangle, Alaska.

INTRODUCTION

In 2006 the Alaska Division of Geological & Geophysical Surveys began investigating the geology and geologic hazards in the proposed natural-gas pipeline corridor through the upper Tanana River valley (Combellick, 2006; Solie and Burns, 2007). Much of this work has involved reconnaissance geologic mapping in a 12 mile wide corridor centered along the Alaska Highway between Delta Junction and the Canadian border. During 2008, while mapping in the Tanacross Quadrangle (fig. 1), we investigated the Tok fan (fig. 2) to try and better understand its development during the last major glaciation. Like Foster (1970) and Carrara (2006), we recognize older and younger parts of the broad, low gradient fan. The western half of the Tok fan is Donnelly (marine oxygen-isotope stage 2) in age. Our discussion here is focused on development of this older fan surface.

TOK FAN MORPHOLOGY AND MATERIAL CHARACTERISTICS

The Tok fan, which occupies most of the Tok–Tanacross basin, was built by streams emanating from the Tok River valley (fig. 2). Although described as an alluvial fan (Williams, 1970, p. 43), this feature lacks properties attributed to typical alluvial fans, including high values of radial slopes, limited radial length, and planoconvex cross profile (Blair and McPherson, 1994, p. 454). The Tok fan is up to 39 km wide, has radii that vary in length from ~13 to ~42 km, and the fan surface slopes from ~1.4 to ~4 m/km.

On the higher, older fan surface, a series of 1- to 3-m-deep, digitate surface channels containing sand fills up to 0.3 m thick, which are locally cross bedded, radiates from the mouth of the Tok River valley toward the fan margins. We measured loess covers that average ~15 cm thick but range from 5 to 56 cm on the older fan surface. The cover of silt on the Tok fan east of the Glenn Highway Tok Cutoff is generally <0.3 m thick, although locally the silt is up to 3 m thick, and the thickness of silt increases close to the Tanana River. A typical post-Donnelly soil profile is developed on this surface (fig. 3).

Examination of numerous gravel pits in the older, higher surface of the Tok fan indicates that this feature is primarily composed of massive pebble gravels with some medium to coarse sand, numerous cobbles, and rare boulders up to ~30 cm diameter. Clasts, which are generally subrounded to rounded and polymictic, generally increase in size toward the apex of the fan. In gravel exposures, Alaska Range lithologies dominate. Holmes (1965, table 4) segregated the lithologies of 100 clasts at five sites on the Tok fan into several classes: dense basalt (48–60 percent, average 54.2 percent), granitic (4–21 percent, average 12.6 percent), vesicular basalt (4–20 percent, average 10.8 percent), quartzite–quartz (3–14 percent, average 7.6 percent), andesite (0–9 percent, average 3.8 percent), gneiss–schist (0–7 percent, average 3.4 percent), and miscellaneous (3–13 percent, average 7.6 percent). The significant percentages of volcanic lithologies are much different than in alluvial fans west of the Tok fan in the Tanana River valley and apparently represent an influx of sediment from volcanic terranes south of the Denali fault (Richter, 1976). Fernald (1965) attributed the source of volcanic erratics in the upper Tanana River drainage to the Nabesna River, a tributary of the Tanana River that drains the Wrangell Mountains. However, we traced vesicular volcanic pebbles and cobbles in gravels for several miles up the Tok River, Little Tok River, and Station Creek valleys away from the Tanana River, and believe that glaciers from the Wrangell Mountains transported volcanic clasts into the headwaters of the Tok River where they were retransported during several glacial outburst floods as suggested by Schmoll (1984) (fig. 2). Along the Tanana River mapping east of the Tok fan failed to identify outburst flood deposits.

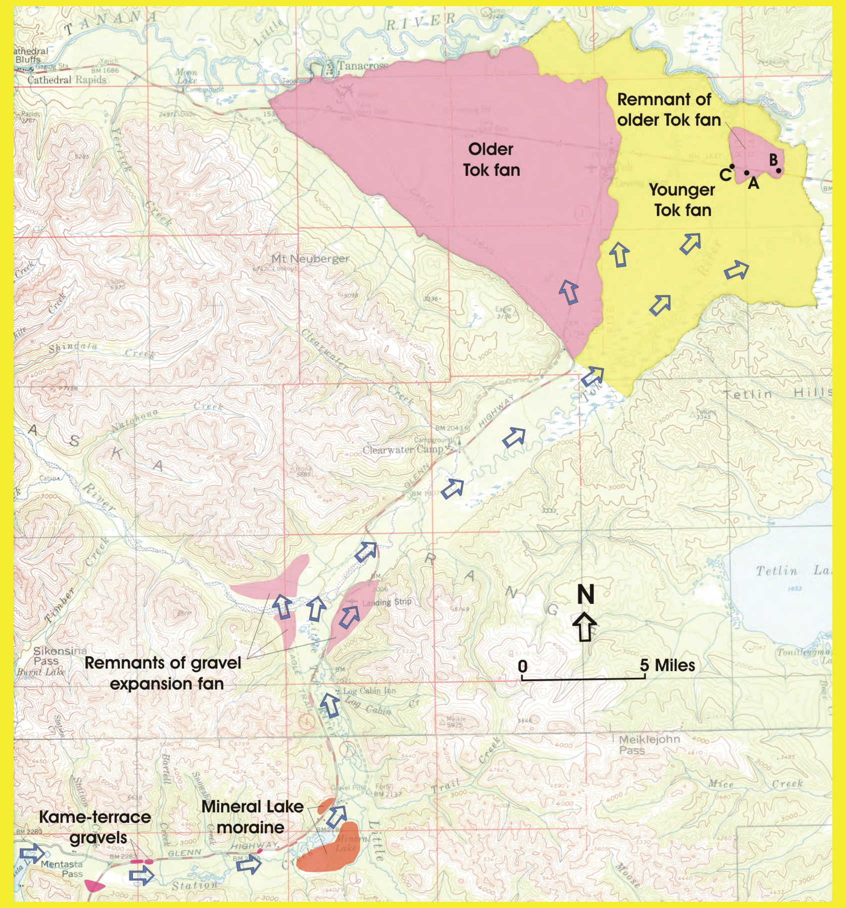

Figure 2. Course of outburst floods (blue arrows) from Mentasta Pass to Tok fan during Donnelly glaciation relative to locations of large boulders in northeastern Tok fan (localities **A–C**). Landforms in upper Tok River and Little Tok River River valleys interpreted in part from Foster (1970) and Richter (1976).

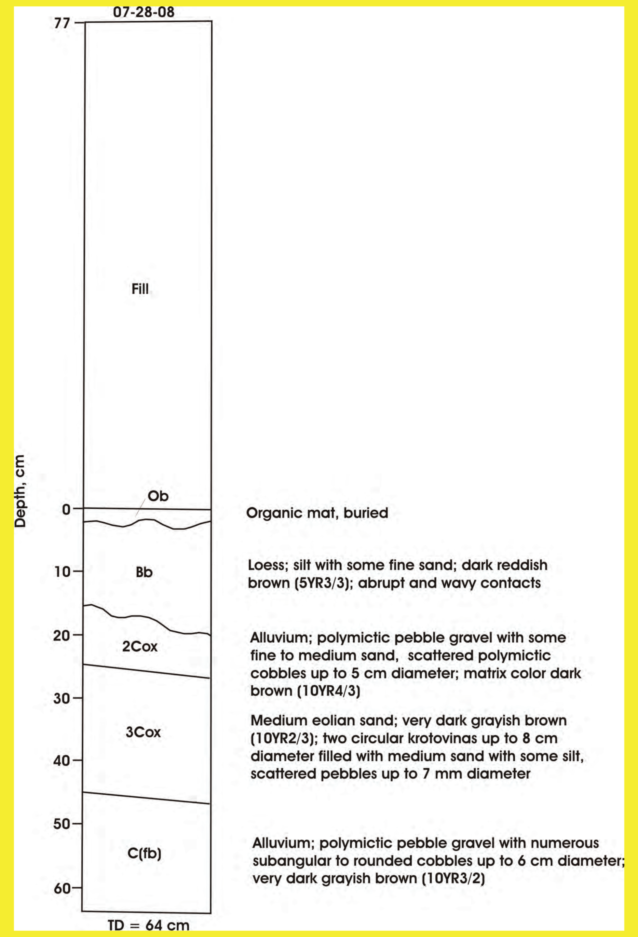

Figure 3. Soil profile (SP-11) exposed in west wall of M.S. 62-2-009-5 in western Tok fan (fig. 2, locality A), in west-central Tanacross B-5 Quadrangle. Elevation 1,554 ft (471 m).

MATERIAL SITE (M.S.) 62-2-005-2

Particularly instructive gravel exposures were discovered in Material Site (M.S.) 62-2-005-2 in an isolated remnant of the older, higher fan surface east of the Tok River (fig. 2, locality A). A 1.8-m greenstone boulder is exposed in place in clast- and matrix-supported gravels in the south pit wall (fig. 4). The bottom of the boulder is 2.4 m below the top of the gravel section in this wall. Near the center of the gravel pit, a pile of six very large boulders of granite, quartz schist, greenstone, and basalt, ranging in maximum diameter from 1.1 to 1.9 m provides evidence that several of these extraordinarily large rocks were encountered during pit excavation. The large in-situ boulder is located in the upper part of a clean, clast-supported pebble gravel with numerous subrounded to rounded, polymictic cobbles and a slight pebble imbrication that indicates flow from the head of the Tok fan. Particularly noteworthy is the presence of a 11-cm-thick zone of disturbance beneath the boulder, perhaps indicating that the underlying material was deformed when the boulder was deposited. In this zone, pebbles are generally oriented parallel to the boulder surface; otherwise, the clast-supported gravel appears massive. The large boulder and the clast-supported gravel are abruptly overlain by matrix-supported massive pebble gravel with scattered small cobbles (fig. 4). Sieve analyses of samples S-9 and S-10 from this unit indicate that the fine fraction represents 5.4 and 2.8 weight percent, the sand fraction represents 12 and 14 weight percent, and the mean grain size is 21.72 and 20.50 mm, respectively (table 1). Beneath the fill at the top of the wall, a layer of loess ~0.5 m thick displays a post-Donnelly soil and is thought to be late Donnelly (MIS2) in age.

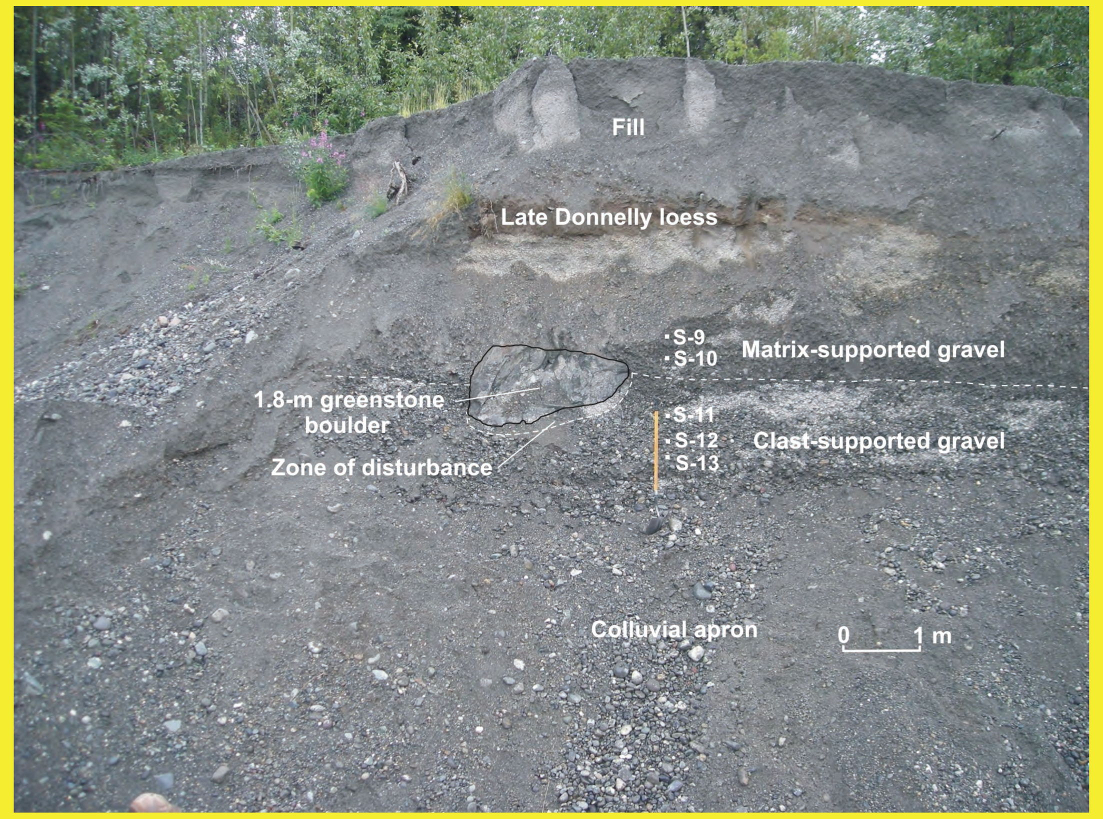

Figure 4. Sample locations and extraordinarily large in-situ greenstone boulder, outlined for clarity, in clast- and matrix-supported gravels in south wall of M.S. 62-2-005-2, northeastern Tok fan, Tanacross B-4 Quadrangle (locality **A**). Photograph taken 07/29/08 by R.D. Reger.

	Size class													
	Gravel							Sand					Fine fraction	
	Particle diameter (mm)													
Sample number	50.8	38.1	25.4	19.0	12.7	9.5	4.75	2.0	0.85	0.425	0.25	0.15	0.075	Mean diameter (mm)
S-1	---	100	94	84	73	60	38	20	13	8	5	4	2.3	6.92
S-2	---	100	97	91	82	77	58	26	10	5	3	2	1.7	3.84
S-3	---	---	100	97	93	88	71	35	8	3	2	1	1.0	2.86
S-4	100	90	88	84	80	74	57	27	12	8	5	3	2.0	3.85
S-5	100	80	69	59	46	39	29	22	19	15	12	8	5.7	14.13
S-6	100	95	85	72	57	50	34	23	18	13	9	6	3.8	9.66
S-7	---	100	87	84	78	72	55	16	4	1	1	1	0.4	4.25
S-8	---	---	100	97	94	92	76	32	7	3	2	2	1.2	2.83
S-9	100	83	55	45	32	27	21	17	15	12	9	7	5.4	21.72
S-10	100	95	62	46	38	32	23	17	13	10	7	5	2.8	20.50
S-11	100	78	55	43	32	24	13	4	2	1	1	1	0.6	22.24
S-12	100	61	46	34	28	25	18	12	8	6	5	3	1.9	27.83
S-13	100	67	59	51	41	31	18	8	4	3	2	1	0.7	18.23
	Percent passing by weight													

Table 1. Grain size distributions of gravels and sands exposed in west wall (samples S-1 through S-8) and south wall (samples S-9 through S-13) of M.S. 62-2-005-2 (locality **A**), Tanacross B-4 Quadrangle (figs. 4 and 6).

Inspection of the nearby pit walls indicates that the interbedded gravel and pebbly sand beds are generally massive, less than 1 m thick, tabular, have abrupt lower and upper contacts, and parallel the fan surface. No cross bedding is present; however, two channel fills were identified, including a 50-cm-thick lens-shaped filling of massive sand in the south wall and a ~1-m-thick channel fill of massive sand overlying clast-supported gravel in the west wall of the pit (fig. 5). Eight samples of clast- and matrix-supported gravels and pebbly sand (S-1 through S-8) were collected from the west wall of M.S. 62-2-005-2 and analyzed for grain-size distribution (fig. 6, table 1). Particularly noteworthy, although not understood, is the ubiquitous presence of vertically oriented pebbles in matrix-supported gravels at the top of the section.

Other extraordinarily large boulders were discovered at localities B and C (fig 2). However, nowhere else in the Tok fan have other extraordinarily large boulders been recovered, even in gravel pits as deep as 10.6 m (Glenn Burnham, 08/05/08, oral commun.), and none were present in the several deep pits we inspected.

Carter and Galloway (1978) apparently saw some of these large boulders, although likely not in place, and mapped the isolated terrace remnant as old glacial moraine which they correlated with moraines of the Delta Glaciation (MIS 4 and 6)to the west. Foster (1970) concluded that the terrace and the older part of the Tok fan west of the Tok River are genetically related and assigned both a Delta age. Carrara (2006) recognized that both surfaces are equivalent and dated them as middle Pleistocene. Based on the presence of post-Donnelly soil profiles and the generally thin cover of loess, we believe that the older part of the Tok fan surface is Donnelly (MIS 2) in age.

Figure 5. Cross section through large channel filling in west wall of M.S. 62-2-005-2, northeast Tok fan, Tanacross B-4 Quadrangle (locality **A**). Contact dotted where inferred beneath colluvial apron. Figure provides scale. Photograph taken 08/01/08 by R.D. Reger.

Figure 6. Locations of samples in exposed gravels and sands in west wall of M.S. 62-2-005-2, northeastern Tok fan, Tanacross B-4 Quadrangle (locality **A**). Photograph taken 08/01/08 by R.D. Reger.

DISCUSSION

The lack of glacial till in any of the water wells or gravel-pit exposures in the Tok fan indicates that the extraordinarily large boulders were not deposited directly from glacial ice as inferred by Carter and Galloway (1978). The absence of stratigraphic features normally formed by water floods, including cut-and-fill structures, ripples, and cross bedding, indicates that the boulders were not deposited by typical water floods. We propose that the very large boulder in the near-surface, tabular, clast- and matrix-supported gravels and pebbly sands in M.S. 62-2-005-2 is evidence that the exceptionally large, rare boulders were deposited as dropstones from icebergs during massive outburst floods emanating from the Tok River valley to the south and spreading as waves (sheetflows) across the shallow fan surface. We speculate that these large boulders were initially dumped near the sites of their ultimate burial and then may have been rolled across the fan surface a very short distance before being quickly buried by subsequent flood pulses. Large boulders carried or moved by the flood have been found in the Tok fan only in line with the trend of the Tok River valley, indicating that the focus of the boulder-bearing outburst floods was in that direction (fig. 2, localities B–C). However, through time gravel-bearing flows must have traversed the fan and deposited the thick gravel layers observed.

The interlayered nature of the tabular gravels and sands enclosing the large flood boulder in M.S. 62-2-005-2 and the clear difference in their compositions (fig. 7 and table 1) indicate that the large-magnitude flows pulsated during the outburst flooding, probably as a result of temporary blockages of subglacial drainageways through which flood waters bypassed the glacier dam (Sturm and others, 1987; Sturm and Benson, 1989; Tweed and Russell, 1999). We suggest that gravel-rich beds represent bedload components deposited by water-dominated flood pulses and that pebbly sands and matrix-supported gravels preserve components of the suspended load that were deposited by watery hyperconcentrated flows. The older part of the Tok fan has morphological characteristics, such as a broad, low gradient, low relief, and a surface network of shallow distributary channels, of a fan dominated by sheetflooding (Blair and McPherson, 1994, fig. 1B).

These massive floods had to occur many times to deliver the huge volume of coarse deposits present in the Tok fan. Inspections of several deep gravel pits indicate that at least the upper 10.6 m of fan sediments accumulated without a significant hiatus during the Donnelly glaciation. Deeper sediments in the Tok fan were likely laid down by pre-Donnelly outburst floods.

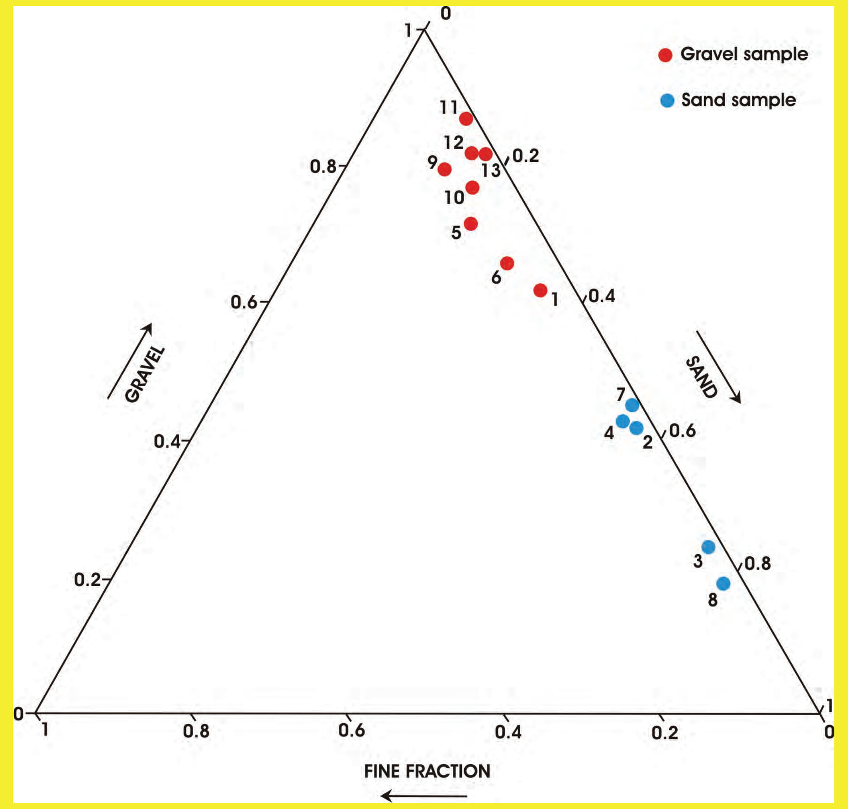

Figure 7. Abundances of gravel, sand, and fine-fraction components in samples of gravel and sand beds in south and west walls of M.S. 62-2-005-2 (table 1), northeastern Tok fan, Tanacross B-4 Quadrangle (locality **A**).

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