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Indian Basin Advance in Western and North-Central Wyoming

Abstract

Three Neoglacial fluctuations are recognized in the mountains of north-central and western Wyoming. The two youngest advances, Gannett Peak (300-100 yr BP) and Audubon (2000-1000 yr BP), are recognized and differentiated on the basis of vegetation and percent of lichen cover, weathering features, and soil development. The name Audubon advance was originally intended for use only in Colorado, but subsequent investigations over the last decade have shown that stratigraphic units of similar description and age are located in the Big Horn, Wind River, and Teton ranges. Because the name Temple Lake has been used for both pre- and post-Altithermal deposits, it is suggested that early Neoglacial deposits (5000?-3000 yr BP) be renamed from a type locality in the northern Wind River Range, Wyoming. After careful scrutiny of several high-altitude areas in the three ranges, Indian Basin was selected as a type locality. In this basin, a series of three end moraines and a medial moraine of early Neoglacial age are found below the Harrower Glacier. Descriptions of the weathering features, lichen characteristics, and soil morphology are used to place these deposits in the Holocene stratigraphic column.

Introduction

Following the Altithermal Interval of Antevs (1948), Neoglaciation led to the renewal of glacial activity in western North America. In the mountains of western and north-central Wyoming three advances during the Neoglacial are recognized. The younger deposits of Gannett Peak and Audubon advances have been mapped and described over much of western Wyoming (Mahaney 1974, 1978; Mahaney *et al.* 1981). Numerous deposits of early Neoglacial (formerly Temple Lake) age have been recognized in several cirques in three ranges. A type locality for these deposits is found in Indian Basin at 3300 m in the Wind River Range (Fig. 1), where the early Neoglacial record is well displayed and exposed. Three distinct sets of end moraines and a medial moraine located downvalley from the Harrower Glacier (Fig. 2) provide a setting in which weathering features, lichen characteristics, and soil morphology can be used to provide a diagnostic body of stratigraphic information. The type locality is used to introduce a new stratigraphic name—Indian Basin advance.

Previous Work

The name Temple Lake was used originally by Moss (1951) to refer to moraines equivalent in age to what eventually became known as Pinedale. Later Richmond (1960, 1962, 1965a, 1965b) used the term Temple Lake to encompass deposits laid down in the early Neoglacial. Benedict (1967, 1968) in the Colorado Front Range used radiocarbon dates, boulder weathering, and lichenometry to provide ages of 5000 to 3000 yr BP for deposits then believed equivalent in age. Because of the age controversy associated with the name Temple Lake, Benedict (1973) renamed early Neoglacial deposits using

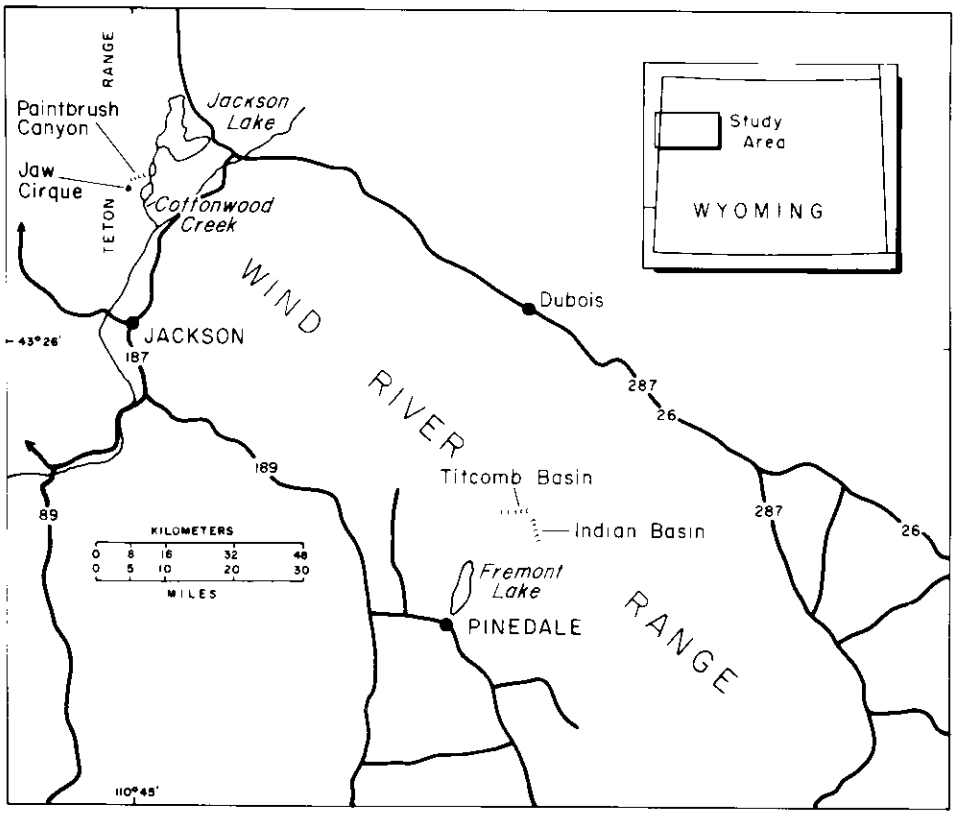

Figure 1. The Wind River Range.

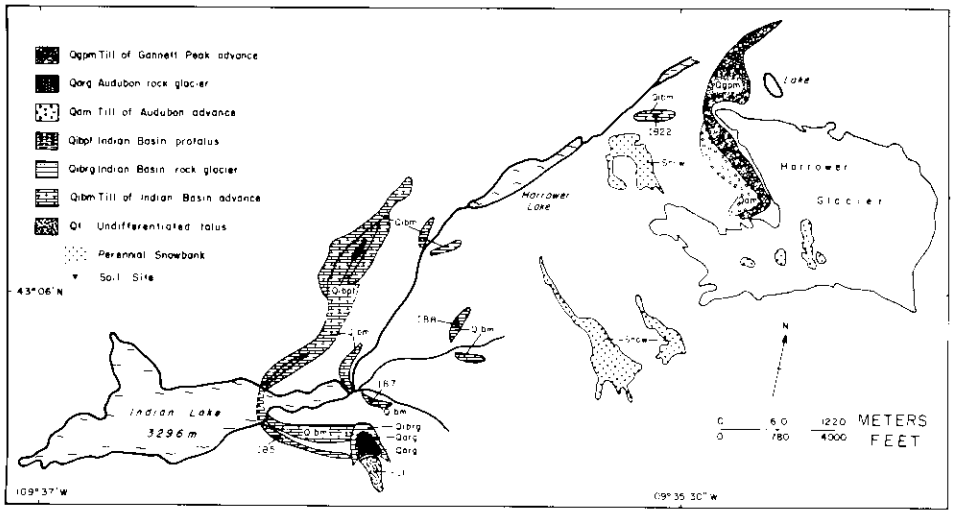

Figure 2. Three distinct sets of end moraines and a medial moraine located downvalley from the Harrower Glacier.

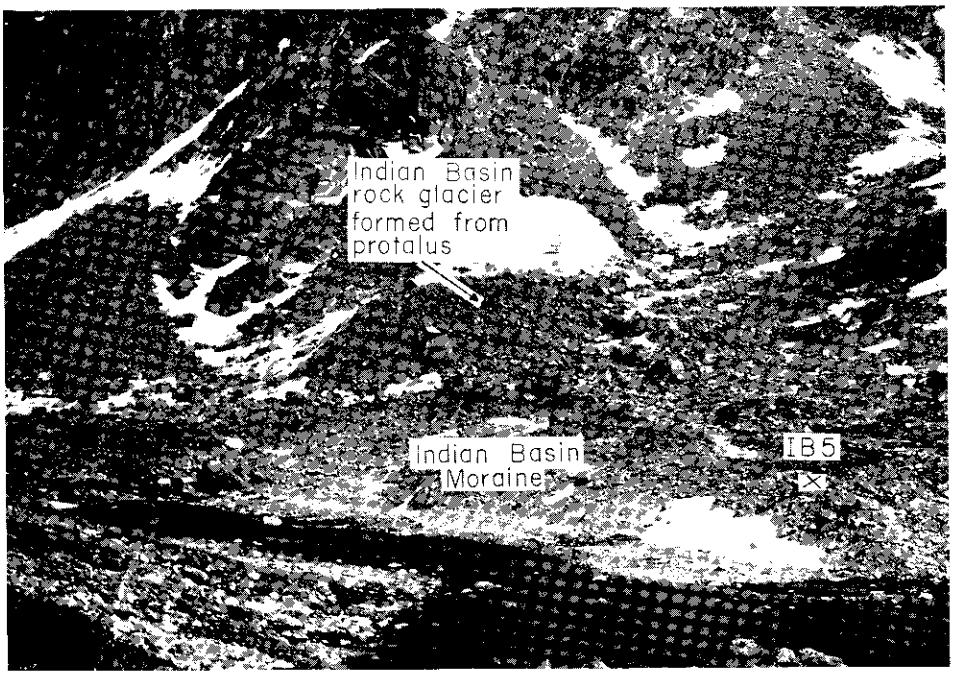

Figure 3. The proposed type area for Indian Basin deposits is located in the valley below Harrower Glacier near Indian Lake.

a Colorado name, Triple Lakes. Recent evidence suggests that some deposits believed to be equivalent in age to the Triple Lakes of Benedict may in fact predate the Neoglacial (Birkeland and Shroba 1974, Meierding and Birkeland 1980).

In Wyoming, the name Temple Lake was retained for early Neoglacial moraines, but the type locality was moved upvalley (south of Temple Lake) (Currey 1974.) At the same time, Miller and Birkeland (1974) pointed out that, "Changing a name or a locality will not solve all the problems," but in this case, retention of the name probably added to the controversy. Following my field work in Temple Cirque (1972), I concluded that the early Neoglacial record at that locality was relatively insignificant, and certainly not representative of other high altitude basins in the Wind River Range. Therefore, I referred to mid-Holocene glacial deposits as early Neoglacial (Mahaney 1975, 1978, 1981). Numerous mapping projects, weathering studies, lichenometric surveys, and soil-profile investigations (Mahaney 1978, 1981; Mahaney *et al.* 1983) showed that early Neoglacial deposits are present in most north-central and western Wyoming cirques, making it advisable to designate with minimum ambiguity the earliest of the Neoglacial advances.

After mapping and collecting samples in three ranges—including Temple Lake (Mahaney *et al.* 1983), Mammoth Basin, Stroud Basin, Titcomb Basin (Mahaney 1978, 1981), and Indian Basin (Mahaney *et al.* 1983) in the Wind River Range; Garnet, Cascade, Jaw, and Paintbrush canyons (Mahaney *et al.* 1981) in the Teton Range; and Cloud Peak Area in the Big Horn Mountains—I suggest that the name Indian Basin be used for early Neoglacial deposits. This decision is made after consultation with the

U.S. Geological Survey Names Committee (M. E. MacLachlan, pers. comm., 1982). The Code of Stratigraphic Nomenclature (A.C.S.N. 1970) contains no guidelines for the use of post-depositional modification such as weathering features, lichen characteristics, and soil morphologies in defining rock-stratigraphic units. Hence, the name Indian Basin is used informally to refer to any early Neoglacial advances that deposited material defined as such by physical characteristics resulting from postdepositional modification (Birkeland *et al.* 1979).

Type Area

The proposed type area for Indian Basin deposits is located in the valley below Harrower Glacier near Indian Lake (Figs. 2 and 3). These deposits have weathering, lichenometric, and soil morphologic features well representative of early Neoglacial deposits recognized in other areas. This is an important area to study because of the proximity of these deposits to younger late Holocene and older early Holocene (late Pinedale) deposits (Figs. 4 and 5), where relative weathering features and soil differences are apparent.

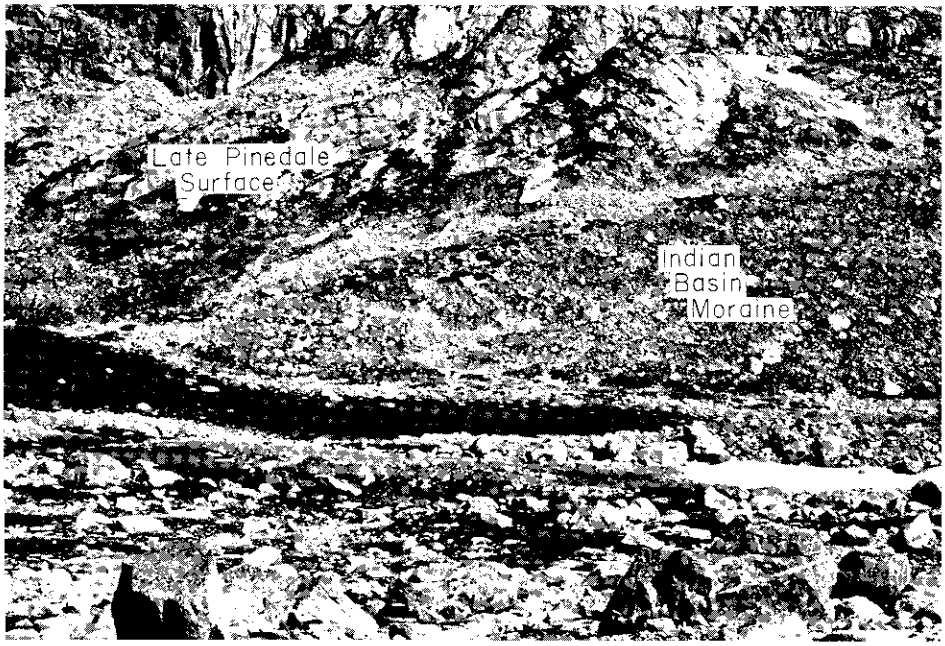

Figure 4. The Indian Basin Moraine and the Late Pinedale Surface.

Weathering Features and Lichenometry

Weathering characteristics, including ratio of fresh to weathered stones weathering rind thickness, and weathering pit depth and width, show that deposits of Indian Basin age are clearly older than deposits of Audubon age and are younger than late Pinedale deposits. The ratio of fresh to weathered stones is not useful in distinguishing between Neoglacial deposits; however, it is useful in separating Neoglacial deposits from older substrates of late Pinedale age (Mahaney 1978, Mahaney *et al.* 1983). In

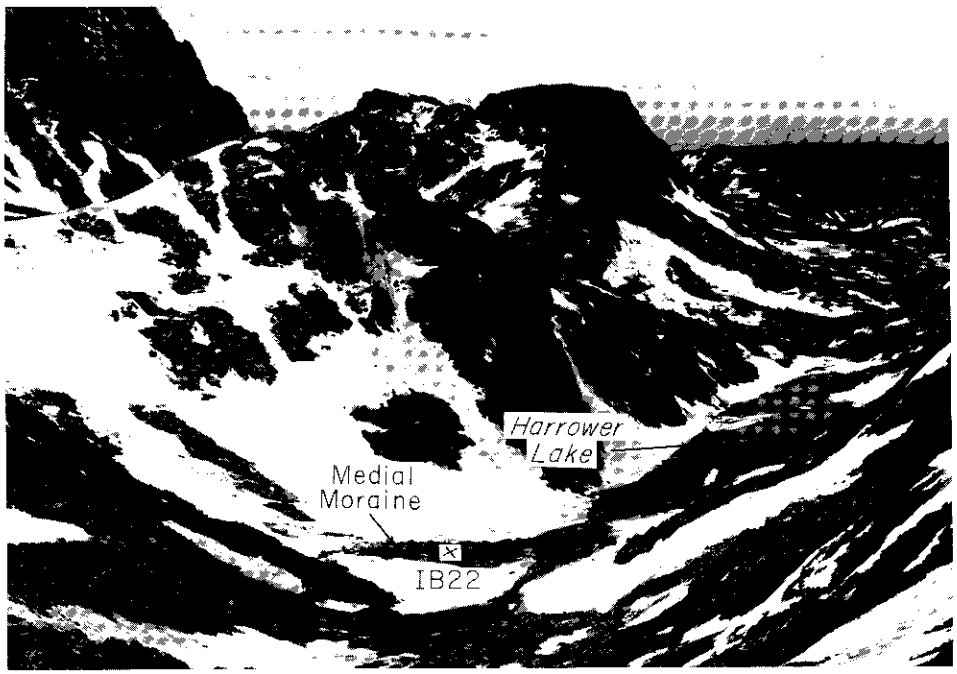

Figure 5. Harrower Lake and the Medial Moraine.

most instances, late Pinedale deposits have ratios of 1 to 3 percent weathered to 99 to 97 percent fresh stones, whereas Neoglacial deposits have 100 percent fresh stones. This observation suggests that weathering ratios are useful age indicators, but not sensitive enough to allow separation of deposits within a glaciation.

Weathering rind development on surface stones is highly variable and produces maximum and minimum thicknesses that vary between deposits of different age. While the maximum rind thickens with age, giving means ($n = 50$ and $n = 100$; Table 1) of 2.1 to 3.6 mm, the minimum rind is nil on Indian Basin deposits. Late Pinedale surface stones, on the other hand, have mean maximum rind thickness of $+5.0$ mm and mean minima are greater than nil (see Mahaney 1978, 1982; and Mahaney *et al.* 1983).

Weathering pit characteristics change with age of the substrate, and they are useful in distinguishing Indian Basin deposits from younger and older units in the geologic succession. For further discussion of the use of this data in age assignment see Mahaney *et al.* 1983.

Maximum lichen diameters and percent cover for the four dominant crustose lichens —*Rhizocarpon geographicum*, *Lecanora thomsonii*, *Lecanora aspicilia*, and *Lecidea atrobrunnea*—are used to distinguish between deposits in the Neoglacial stratigraphic succession. Lichen on surfaces of late Pinedale age are beyond the range of lichenometry. The data in Table 1 are useful in distinguishing among Neoglacial advances (*e.g.*, Gannett Peak, Audubon, and Indian Basin). Among the above four dominant crustose lichens, *R. geographicum* and *L. thomsonii* are the most significant because their maximum diameters fall into three discrete groups. *Lecidea aspicilia*, although absent on the youngest deposits of Gannett Peak age, occurs on older substrates. *Lecidea atrobrunnea*, absent

TABLE 1. Weathering characteristics[a], lichen thalli diameters, and percent lichen cover for sites on Figure 2, Indian Basin, northern Wind River Range, Wyoming.

Site[b]	Weathering Rinds Max	Min	n	R. geographicum	L. thomsonii	L. aspicilia	L. atrobrunnea	% Cover
IB5[c]	2.1	nil	50	72	110	148	118	50+
IB7	3.6	nil	100	85	98	140	121	50+
IB8	3.0	nil	50	70	101	160	36	30-50+
IB22	2.8	nil	50	39	106	151	105	15-80

[a]Measurements in millimeters
[b]For location see Figure 2
[c]Samples taken from B horizon in soil pit

on deposits of Gannett Peak age, appears on Audubon and Indian Basin deposits. Most significantly, percent of lichen cover, ranging from nil on Gannett Peak deposits to 15-30 percent on Audubon deposits, increases to more than 50 percent on Indian Basin surfaces.

Soils

Differentiation of Neoglacial deposits is further supported by soil morphological and clay mineralogical data. I have described and sampled 28 soil profiles of early Neoglacial age forming in topographically high and well-drained sites, in the alpine vegetation and climatic zones, and in materials consisting largely of till with clasts of granite and granodiorite. The IB5 soil profile (Table 2) is representative of early Neoglacial profiles sampled in the Wind River, Teton, and Big Horn ranges.

TABLE 2. Soil profile[a] IB5 in Indian Basin, Wind River Range.

Horizon	Depth (cm)	Description
01	1-0	Black (10YR 1.7/1; 2/1)
A1	0-7	Grayish yellow brown (10YR 4/1m), and dull yellowish brown (10YR 5/3d) sandy loam, granular structure, friable moist consistence, slightly plastic and non-sticky.
IIB	7-20	Dull yellowish brown (10YR 5/4m), brown (10YR 4/4m), and dull yellow orange (10YR 7/3d) pebbly sandy clay loam, weak blocky structure, friable moist consistence, nonplastic and slightly sticky.
IICox	20-69	Dull yellowish brown (10 4/3m, 5/3m) yellowish brown (2.5Y 5/3m), and dull yellow orange (10YR 7/2d) pebbly sandy loam, massive, friable moist consistence, nonplastic and nonsticky.
IICn	69+	Dark olive (5Y 4/3m) and light gray (2.5Y 8/2d) pebbly sandy clay loam, massive, friable to very friable moist consistence, nonplastic and nonsticky.

[a]Soil descriptions follow Soil Survey Staff (1951) and Birkeland (1974); soil colors are from the standard Soil Color Charts of Oyama and Takehara (1967) and are given in the moist (m) and dry (d) states.

The post-Indian Basin soil, an Inceptisol tentatively classified as a Dystric Cryocrept according to criteria of the Soil Survey Staff (1975) is representative of early Neoglacial soils studied in several high-altitude basins. This soil contains clear and distinct horizon

contacts to a depth of 69 cm. Horizon identity rests on color changes, with soil showing 10YR and the parent material 2.5Y hues. Sandy and sandy clay loam textures dominate throughout the profile, with high percentage of pebbles and cobbles in the lower solum and subsoil. Textures become finer with depth in the profile as clay increases downward, possibly a result of illuviation (Table 3). Granular structure in the A1 horizon

TABLE 3. Particle-size distributions for the soil horizons in the >2mm and <2mm fractions of four post-Indian Basin profiles, type area, northern Wind River Mountains, Wyoming.

Site	Horizon[b]	Depth (cm)	Location[a]	Pebbles %	Sand-Silt-Clay %	Sand % (2mm-63μm)	Silt % (63-4μm)	Clay % (<4μm)
IB5	A1	0-7	Outer	15.5	84.5	53.6	25.9	20.5
	IIB	7-20	End	26.8	73.2	61.4	14.6	24.0
	IICox	20-69	Moraine	25.3	74.7	62.3	15.2	22.5
	IICn	69+		33.2	66.8	62.5	14.0	23.5
IB7	A1	0-8	Intermediate	19.3	80.7	53.3	30.7	16.0
	IIB	8-20	End	32.4	67.6	68.1	25.4	6.5
	IIC1ox	20-53	Moraine	44.3	55.7	65.1	23.9	11.0
	IIC2ox	53-72		42.5	57.5	67.8	21.7	10.5
	IICn	72+		39.3	60.7	65.3	22.7	12.0
IB8	A1	0-9	Inner	9.9	90.1	33.3	35.7	31.0
	B	9-28	End Moraine	30.7	69.3	35.9	36.6	27.5
	IIC1ox	28-55		68.9	31.1	78.8	14.2	7.0
	IIC2ox	55-83		70.4	29.6	83.4	12.9	3.7
	IICn	83+		31.5	68.5	78.2	17.0	4.8
IB22	A1	0-6	Medial	23.9	76.1	63.4	23.6	13.0
	B	6-18	Moraine	23.5	76.5	53.8	32.7	13.5
	Cox	18-80		54.0	46.0	62.7	30.5	6.8
	IICn	80+		50.7	49.3	70.0	17.0	13.0

[a]For location see Figure 2.
[b]Till/loess boundary (II/I) determined by high silt in the solum or subsoil.

and a weak grade of blocky structure in the B horizon are characteristic of post-Indian Basin soils (Mahaney 1982). Oxidation effects deduced from soil hues (10 YR 4/4m in the B horizon) suggest some chemical weathering.

Mineral material finer than 2mm is dominantly sand in most cases (Table 3). In all profiles there is an upward fining sequence of silt, suggesting airfall influx of material. In most instances, the high silt layer forms a cap on the soil profile; however, in profile IB22 it appears to be a mechanical mix of loess and till to a depth of 80 cm. Clay ($<4\mu m$) is generally highest in the sola of the three soils, presumably the result of weathering *in situ* and aeolian influx. However, in profile IB5 clay increases somewhat in the lower solum, and overall it is fairly uniformly distributed with depth.

Mineralogical analysis of the clay grade size ($<2\mu m$) was carried out by X-ray diffraction, following procedures outlined by Whittig (1965). The results in Table 4 show little variation within the primary mineral suites. However, lower quartz and feldspar in the solum of IB8 may be the result of weathering since the middle phase of early Neoglaciation. Differences in clay mineral composition show that illite, which is highest in the parent materials (Cn horizons), decreases or disappears altogether in the soil sola where smectite and illite-smectite tend to increase. However, in the IB8 profile smectite and illite-smectite are abundant in the subsoil and parent material. Over-

TABLE 4. X-ray analysis of the <2μm fraction of four post-Indian Basin soils, type area, northern Wind River Mountains, Wyoming.

Site	Horizon	Depth (cm)	K	H	I	S	I-S	V	C	Q	P
IB5	A1	0-7	tr	—	—	—	—	tr	—	xxx	x
	IIB	7-20	xx	?	x	xx	xx	—	x	xxx	x
	IICox	20-60	x	tr	x	x	x	—	x	xxx	x
	IICn	60+	x	tr	x	x	x	—	x	xx	x
IB7	A1	0-8	xxx	xx	x	xxx	xxx	xx	xx	xxx	xxx
	IIB	8-20	xxx	xx	x	xxx	xxx	xx	xx	xxx	xxx
	IIC1ox	20-53	xxx	xx	xxx	xx	xxx	xxx	xx	xxx	xx
	IIC2ox	53-72	—	x	xxx	—	xxx	xxx	xx	xxx	xxx
	IICn	72+	—	tr	xx	—	xxx	xx	x	xxx	xxx
IB8	A1	0-9	—	—	tr	tr	x	x	x	x	x
	IIB	9-28	—	tr	—	tr	tr	tr	tr	—	x
	IIC1ox	28-55	xx	tr	—	xxx	xxx	xxx	xx	xxx	xxx
	IIC2ox	55-83	xxx	tr	x	xxx	xxx	xxx	xxx	xxx	xxx
	IICn	83+	xxx	?	x	xxx	xxx	xx	xxx	xxx	xx
IB22	A1	0-6	?	—	—	?	tr	—	—	xxx	xx
	B	6-18	tr	—	x	xx	xx	x	x	xxx	xx
	Cox	18-80	tr		x	tr	x		—	xxx	xx
	IICn	80+	tr	—	xxx	x	x	—	x	xxx	xx

[a]Minerals are kaolinite (K), halloysite (H), illite (I), smectite (S), illite-smectite (I-S), vermiculite (V), chlorite (C), quartz (Q), plagioclase feldspar (P). Mineral amounts are given semi-quantitatively as nil (—), minor amount (tr), small (x),, moderate (xx), and abundant (xxx).

all, the relative increase of smectite in the B and C horizons of post-Indian Basin profiles (relative to the parent materials) is part of a general pattern observed in other soil chronosequences in the Wind River Range. On the other hand, post-Indian Basin soils in the Teton Range have little smectite, a characteristic attributed to the parent material, which is composed largely of felsic gneiss and granite.

Conclusions

The data discussed herein are intended to provide a corpus of stratigraphic information to be used to recognize deposits of Indian Basin age in the mountains of western Wyoming. These deposits have weathering, lichenometric and soil morphologic features that are diagnostic of early Neoglacial deposits recognized in many high altitude valleys of the Teton, Wind River, and Big Horn ranges. While weathering criteria allow separation of Indian Basin substrates from older late Pinedale deposits, the most important relative dating methods for subdividing deposits within the Neoglacial include lichen characteristics and the degree of soil development. An important characteristic of post-Indian Basin soils is that they often contain moderate to large amounts of smectite and illite-smectite, apparently the result of weathering from illitic-rich parent materials.

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Received July 6, 1983
Accepted for publication October 18, 1983