The Skolai Group in the McCarthy B-4, C-4, and C-5 Quadrangles, Wrangell Mountains, Alaska

By JAMES G. SMITH *and* E. M. MACKEVETT, JR.

CONTRIBUTIONS TO STRATIGRAPHY

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Definition and description of a new low-grade metamorphic sequence

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ABSTRACT

The Skolai Group, named in this report, is a thick sequence of low-grade metamorphic rocks that consists of lava flows and overlying volcaniclastic and sedimentary rocks, all of marine origin. Rocks of the group are widely distributed in the eastern Wrangell Mountains and nearby parts of Alaska and Canada. The Skolai Group is divided into the Station Creek Formation and the Hasen Creek Formation. The Station Creek Formation, the older of the two, contains a volcanic flow member and an overlying volcaniclastic member. The Hasen Creek Formation consists mainly of thin-bedded chert, black shale, sandstone, and limestone; a thick lenticular bioclastic limestone near the top of the Hasen Creek Formation is named the Golden Horn Limestone Lentil. No exposures of the base of the Skolai Group were found. The youngest known rocks that are regionally subjacent to the group locally contain Mississippian fossils and are more deformed and more metamorphosed than rocks of the Skolai Group. Rocks of the Skolai Group are overlain locally by fossiliferous Middle Triassic rocks, probably with slight unconformity, and overlain extensively by the Nikolai Greenstone (late Middle and (or) early Late Triassic) or by Tertiary rocks, with slight to strong angular unconformity. The Skolai Group is believed to be largely or entirely Early Permian in age. No fossils were found in the Station Creek Formation, but fossils indicative of Early Permian age are abundant in parts of the overlying Hasen Creek Formation, particularly in its Golden Horn Limestone Lentil.

INTRODUCTION

A thick sequence of slightly metamorphosed sedimentary and volcanic rocks that are widely distributed in the Wrangell Mountains, Alaska, and in nearby parts of the Yukon Territory is described in this report. A new name, the Skolai Group, is proposed for this sequence.

This report is based on geologic investigations in the McCarthy C-4, B-4, and C-5 15-minute quadrangles (fig. 1; pl. 1) in the Wrangell Mountains (MacKevett and others, 1964; MacKevett, 1963, 1969;

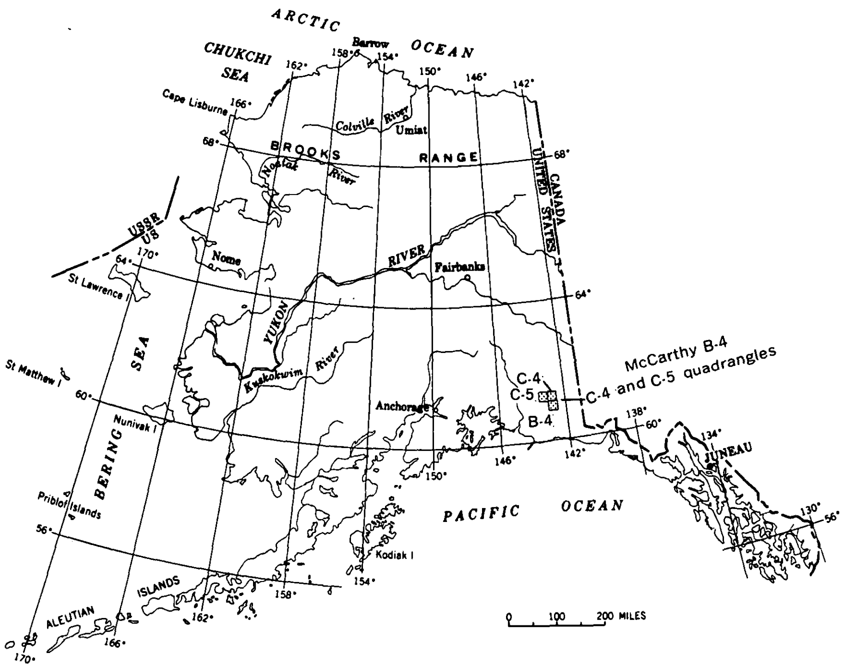

FIGURE 1.—Location of the McCarthy B-4, C-4, and C-5 quadrangles.

MacKevett and Smith, unpub. data, 1969). In the C-4 quadrangle this sequence was mapped by George Plafker and subordinately by MacKevett and H. C. Berg. In the C-5 quadrangle it was mapped by MacKevett, and in the B-4 quadrangle by Smith and subordinately by MacKevett and G. R. Winkler. The mapping utilized U.S. Geological Survey topographic bases at a scale of 1:48,000 and was implemented by aerial photographs. The fieldwork was helicopter supported. Relevant laboratory studies included petrographic examinations of thin sections, some X-ray diffraction, chemical and semiquantitative spectrographic analyses, and supplementary paleontologic studies.

The sequence consists of extensive lava flows and volcaniclastic sedimentary rocks and subordinate overlying clastic and chemical deposits that contain a limestone lentil. It is probably entirely Early Permian in age, although age data are lacking on its basal volcanic flow and volcaniclastic units. Rocks of the sequence have been described in earlier reconnaissance studies, notably by Moffit (1938, p. 29–37; 1954, p. 103–118). Similar rocks in the Yukon Territory have recently been described by Muller (1967, p. 33–43).

SKOLAI GROUP

NAME AND GENERAL RELATIONS

The name Skolai Group is here applied to the thick sequence of low-grade metamorphic, predominantly volcanic and volcaniclastic rocks that are well exposed along the upper reaches of Skolai Creek and the Chitistone River and their tributaries (pl. 1). The group's type area is designated as the area extending southeastward from near the southwest corner of sec. 15, T. 2 S., R. 17 E. (Copper River meridian) to the terminal moraine of Frederika Glacier in the McCarthy C-4 quadrangle (pl. 1). The group is more than 8,000 feet thick (fig. 2), at its type area viewed in figure 3. A reference section for the Skolai Group is designated in secs. 26, 27, 33, 34, and 35, T. 5 S., R. 18 E. along upper Glacier Creek near the east border of the McCarthy B-4 quadrangle (pl. 1; fig. 2). This section is more attenuated than that at the type area and forms a homoclinal sequence more than 5,500 feet thick that represents mainly the middle part of the group.

The name Skolai Group is taken from Skolai Creek in the C-4 quadrangle. The name Skolai Volcanics, originally proposed by Rohn (1900, p. 429), was abandoned and invalidated by the Geologic Names Committee of the U.S. Geological Survey following a written request by Mac Kevett in 1968, mainly because the name pertains to rocks that recent mapping has shown to include the Nikolai Greenstone and Wrangell Lava but also because the name has been in disuse for several decades.

The base of the Skolai Group has not been recognized either by us or by earlier investigators. In the McCarthy B-4 and C-4 quadrangles, the Skolai Group is overlain locally by Middle Triassic sedimentary rocks and more extensively by the Nikolai Greenstone (late Middle and (or) early Late Triassic), or the Wrangell Lava (Tertiary and Quaternary), or the Frederika Formation (Tertiary) (MacKevett, 1963, 1969; MacKevett and Smith, unpub. data, 1969). Its contacts with Middle Triassic rocks are difficult to discern, but the contacts probably are slightly discordant. Contacts with the Nikolai Greenstone are without doubt slightly to moderately discordant, and those with the Wrangell Lava and the Frederika Formation are marked by strong angular unconformities. Rocks of the Skolai Group have been intruded by gabbro that commonly forms large discordant or concordant masses and, less commonly, dike-like and sill-like salients; the rocks are also cut by a few small felsic plutons and by andesitic dikes. Locally the Skolai Group is overlain by Quaternary surficial deposits.

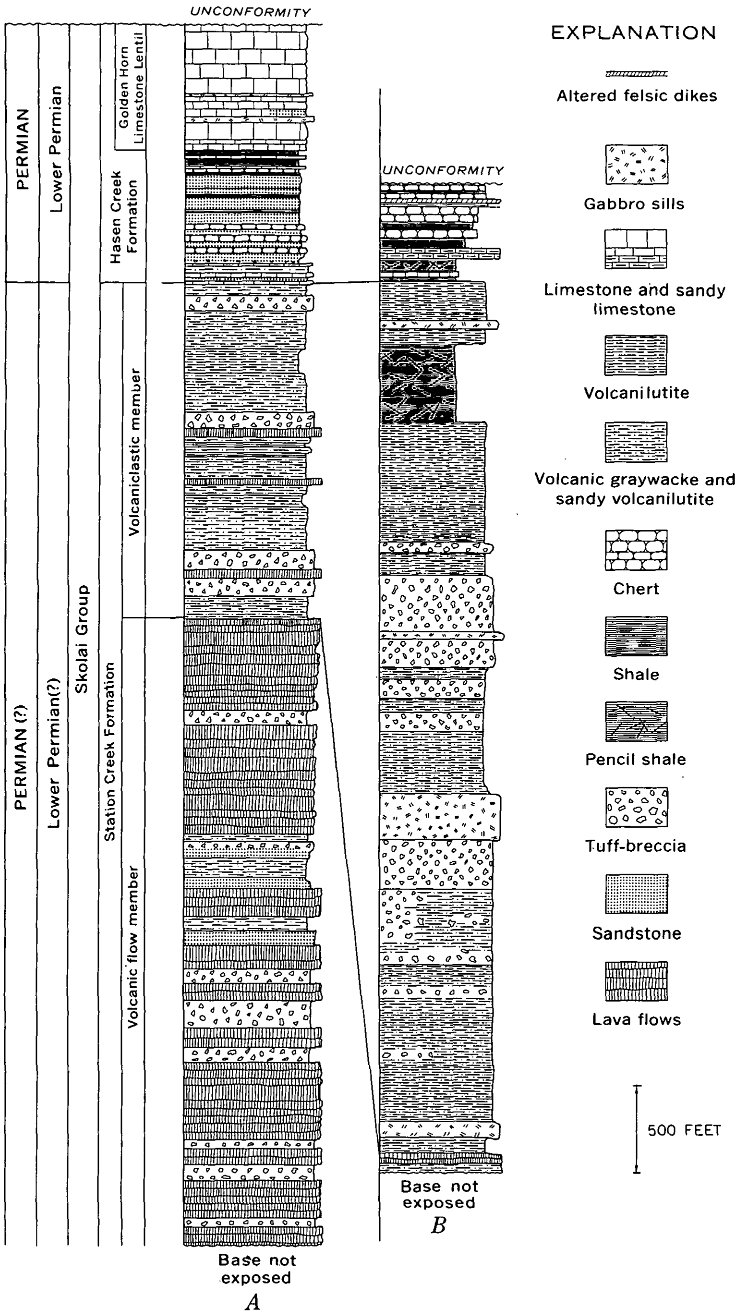

Figure 2.—Generalized columnar sections of the Skolai Group. *A*, Type area between the Golden Horn and Frederika Glacier in the McCarthy C–4 quadrangle. *B*, North of Glacier Creek near the east edge of the McCarthy B–4 quadrangle.

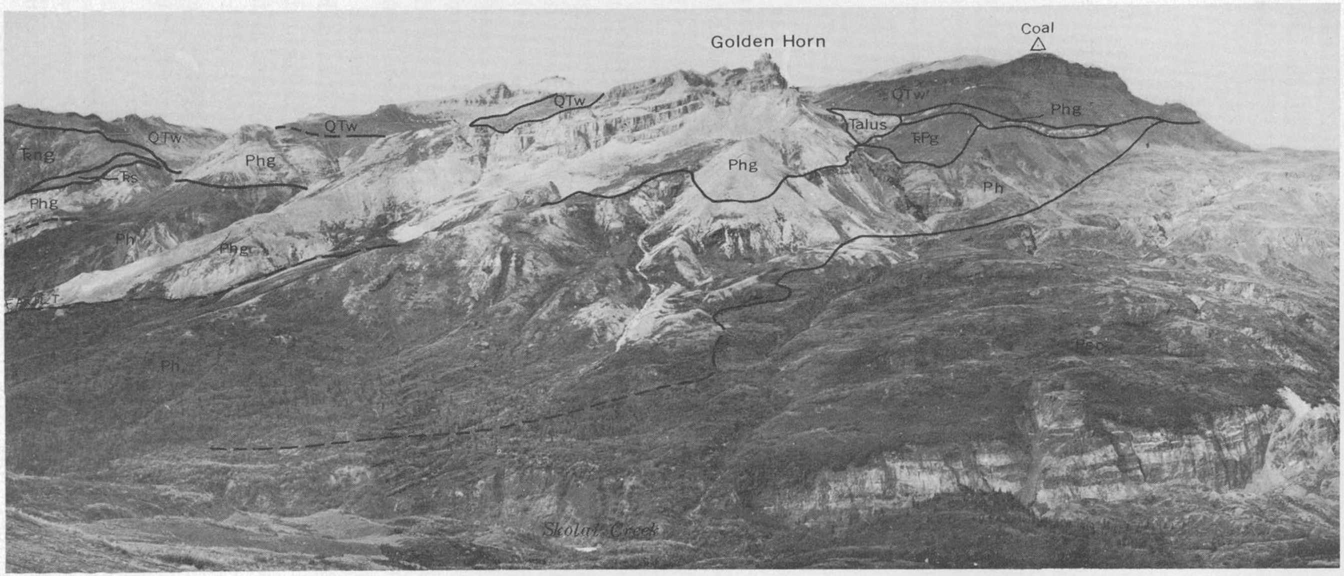

FIGURE 3.—The type area of the Skolai Group. Photograph taken south of Skolai Creek looking north toward the vicinity of the Golden Horn. QTw, Wrangell Lava; TRng, Nikolai Greenstone; TRs, shale and siltstone containing the pelecypod *Daonella;* TRPg, gabbro; Ph, Hasen Creek Formation; Phg, Golden Horn Limestone Lentil; Psc, volcaniclastic member of the Station Creek Formation.

The Skolai Group is divided into the Station Creek and Hasen Creek Formations. The Station Creek Formation, the older of the two, includes two informal members, and the Hasen Creek Formation includes the Golden Horn Limestone Lentil.

STATION CREEK FORMATION

The Station Creek Formation is named here for Station Creek, an eastward-flowing tributary of Frederika Creek in the northeastern part of the McCarthy C–4 quadrangle (fig. 1). The formation's type area is designated to be the area that extends for about 3½ miles west from about a mile south of Station Creek. The formation is divided into two informal members, a lower volcanic flow member and an upper volcaniclastic member.

VOLCANIC FLOW MEMBER

DISTRIBUTION AND GENERAL DESCRIPTION

The volcanic flow member of the Station Creek Formation is well exposed at the formation's type locality, in the southeastern part of the McCarthy C–4 quadrangle, and near the east border of the McCarthy B–4 quadrangle (pl. 1). It consists mainly of basalt and basaltic andesite flows.

The volcanic flow member is approximately 4,000 feet thick at its type locality. Possibly the section shows some repetition because of faulting, but no faults with large displacements were found during mapping. The base of the volcanic flow member is not exposed within the mapped area (pl. 1), and brief examinations of nearby areas also failed to disclose it. The nearest outcrops of older, more deformed rocks belong to the Mississippian Strelna Formation and are in the McCarthy A–4 quadrangle (Miller and MacColl, 1964) about 8 miles south of the southernmost exposures of the Skolai Group in the C–4 quadrangle; however, rocks of the two units are not in contact. Both Moffit (1938, p. 30) and Muller (1967, p. 37) were unable to find the base of rocks correlative with the Skolai Group. Nevertheless, a structural discontinuity between the Skolai Group and the Strelna Formation is indicated by the higher metamorphic grades and greater deformation of the Strelna. Such a discontinuity was postulated by Muller (1967, p. 37) between correlative rocks in the Yukon Territory.

Contacts between the volcanic flow member and the overlying volcaniclastic member, which were seen in only a few places, are gradational over a few hundred feet. Going up-section, lava flows are interbedded with increasing numbers of volcaniclastic beds.

Individual flows of basalt and basaltic andesite constitute more than 75 percent of the volcanic flow member. Coarse-grained volcaniclastic rocks, mainly pillow breccias and tuff-breccias, and to a lesser extent uncommon fine-grained volcaniclastic sedimentary rocks and dacite and andesite flows constitute about 25 percent of the member.

Measurement of flow thickness and determination of tops, flow direction, and other characteristics are usually only approximate and often impossible to make, owing to the massiveness and similarity of the flows and to the metamorphic overprinting; therefore, all figures below should be considered as estimates. Most flows are 10–100 feet thick, but massive flows as thick as 200 feet were recognized near the toe of Chitistone Glacier. Thicker flows often grade upward into pillow complexes, pillow breccias, and broken pillow breccias. Generally the individual flows are stacked one on top of the other without any interflow sediments.

The Skolai Group's lavas flows, which have resisted glacial erosion more than most of the group's sedimentary rocks, form either smooth, glacially polished outcrops with numerous cliffs or steep slopes covered with small sharp talus fragments.

Both fresh and weathered outcrops of flows are somber tones of black or dark greenish gray. The glint of plagioclase microlites set in the otherwise dull and dark groundmass helps to distinguish these flows from fine-grained gabbro and younger volcanic flows. From a distance, the flows appear massive and unbroken, but when struck with a hammer, they break along joints spaced a few inches apart.

PETROGRAPHY

Amygdules and phenocrysts are abundant in most of the basalts and basaltic andesite flows. The amygdules are spherical to slightly flattened, are 1–10 millimeters across, and are filled with mixtures of zeolites, albite, chlorite, calcite, and quartz. They constitute as much as 20 percent of flows. The phenocrysts are composed of plagioclase and pyroxene, occur in most flows, but range widely in abundance. The plagioclase phenocrysts are more abundant and better preserved. Nearly all original plagioclase phenocrysts are now milky white or pale green in hand specimen and turbid in thin section owing to metamorphic recrystallization. Relict phenocrysts typically form euhedral tablets 1–4 mm long that make up less than 5 percent of a flow. Complex oscillatory zoning is rarely preserved, but relict twinning with many narrow complex twins is still preserved in all but the most recrystallized specimens. Most plagioclase is now metamorphic albite, but the few unmetamorphosed relicts are andesine or sodic labradorite.

Equant euhedral to subhedral pyroxene phenocrysts approximately 2 mm across make up as much as 10 percent of the flows. They are dark green to black under the hand lens and colorless in thin section. Estimation of optic properties gives $2V = (+)40°–60°$ and $Z \wedge c$ of 40°–45°, indicating a calcium-rich augite. Like plagioclase, pyroxene was altered severly during metamorphism, largely to clots of feathery green chlorite.

Delicate original groundmass textures were largely destroyed by metamorphic recrystallization, but most of the lavas probably had intersertal or intergranular textures. Plagioclase microlites as long as 1 mm are clearly visible in most specimens. They are now albite, although originally they were more calcic. Euhedral grains of opaque minerals (mainly magnetite and ilmenite) are the only other original minerals preserved. These original opaque grains are no larger than 0.5 mm and are scattered throughout the groundmass. Many still smaller opaque anhedra are also present, but most of these formed by metamorphic recrystallization of the original fine-grained groundmass. Other metamorphic minerals which recrystallized from the original groundmass include chlorite, quartz, sphene, ilmenite, actinolite, calcite, albite, biotite, hematite, prehnite, pumpellyite, "sericite," and clinozoisite-epidote. The last three are also common metamorphic products of plagioclase.

Chemically, the flows (tables 1, 2) resemble greenstones described by Bailey, Irwin, and Jones (1964, p. 1952) from the Franciscan Formation of California. Norms of 62AMk–150, 62AMk–151, and 67ASj–228B would indicate that these basalts might be classified as undersaturated olivine tholeiites, for both olivine and hypersthene are present in the norm (Yoder and Tilley, 1962). They differ significantly, however, from normal undersaturated olivine tholeiites in that they carry almost no olivine in the mode and are too low chemically in calcium (this is especially true if the calcium needed to make calcite is subtracted) and magnesium and too high in soda. Two of our samples are highly altered (62AMk–150, 62AMk–151), and this alteration is reflected in the analyses by high CO_2 and high combined water; calcite fills amygdules, and calcite veinlets cut the rock. The other two samples (67ASj–228B, 62Apr–4a) are fresher in thin section, and their analyses reflect this by showing negligible CO_2; combined water is high, however, owing in part to the formation of hydrated greenschist facies minerals. Since eruption, the Skolai lavas, like the Franciscan lavas, undoubtedly have gained and lost large amounts of major constituents, but there is no way of estimating which constituents have been exchanged.

Volcaniclastic rocks make up less than 20 percent of the volcanic flow member of the formation. In general the volcaniclastic rocks of the member are similar to those in the overlying volcaniclastic member. They are interbedded with flows and consist of tuff-breccia and poorly sorted volcanic conglomerate and subordinate volcanic graywacke and volcanilutite (terminology of Fiske and others, 1963, p. 4). Individual beds are 1–100 centimeters thick, and most beds are about 10 cm thick. Packages of volcaniclastic beds of a few meters to a few tens of meters are sandwiched between much thicker flow sequences. All the volcaniclastics show their direct derivation from contemporaneous flow rocks by the composition of their poorly sorted and rounded clasts, which are mineralogically and texturally identical to those of the flows.

VOLCANICLASTIC MEMBER

DISTRIBUTION AND GENERAL DESCRIPTION

The volcaniclastic member of the Station Creek Formation is well exposed in a broad northwest-trending band, which extends across the southeastern part of the McCarthy C–4 quadrangle and along the east border of the McCarthy B–4 quadrangle (pl. 1). This member is particularly well exposed on the slopes below the Golden Horn between Skolai Creek and Frederika Glacier and along the edges of the northern tributaries to Glacier Creek Glacier.

The volcaniclastic member is a heterogeneous mixture of volcaniclastic rocks ranging from coarse volcanic breccia to delicately laminated volcanilutite. Nonvolcanic detritus is absent. Flows are confined to the lower part of this member and make up less than 15 percent. Fine-grained volcaniclastics are more prevalent near the top, and the upper 500 feet is nearly all volcanic siltstone and volcanilutite.

This member is more than 2,500 feet thick near Glacier Creek and about 2,000 feet thick near Skolai Creek. Its thickness, however, ranges greatly from place to place.

The contact between the volcaniclastic member and the underlying volcanic flow member is gradational over a few hundred feet. Also, it is quite likely, because of the accumulation of lenses of lava flows and intertonguing, that the contact was not everywhere drawn on the same horizon.

The volcaniclastic member contains both polymict and monolithologic coarse volcaniclastic beds and units made of sequences of similar beds, but there is no particular order to a sequence of beds. Most volcaniclastic beds appear to extend laterally for great distances, and across unvegetated uplands and along cliffs individual beds extend without change for distances of as much as one-half mile before being covered.

TABLE 1.—*Chemical analyses and molecular norms of rocks from the Skolai Group*

[Rapid rock analyses: samples 1–6 by P. L. Elmore, S. D. Botts, Lowell Artis, Hezekiah Smith, and John Glenn; samples 7–10 by P. L. Elmore, S. D. Botts, Lowell Artis, Hezekiah Smith, John Glenn, G. W. Chloe, and James Kelsey]

	Hasen Creek Formation				Station Creek Formation					
	Golden Horn Limestone Lentil		Permian(?) sedimentary rocks		Volcaniclastic member		Volcanic flow member			
Sample	1	2	3	4	5	6	7	8	9	10
Laboratory No.	165386	165387	165383	165381	165385	165382	M104877W	M104876W	M104879W	M104878W
Field No.	62AMk-213	62AMk-214	62AMk-163	62AMk-117	62AMk-247	62AMk-125	62AMk-151	62AMk-150	67ASj-288B	62Apr-4a
Chemical analyses										
SiO_2	2.3	2.0	87.9	59.7	59.7	65.6	45.4	46.2	50.6	59.7
Al_2O_3	.56	.45	2.3	13.3	17.5	14.3	16.0	15.8	17.5	14.6
Fe_2O_3	.19	.08	.28	1.7	3.0	1.7	2.3	2.3	3.4	3.1
FeO	.04	.10	.10	3.6	2.1	3.0	8.6	8.0	5.5	5.7
MgO	.49	.43	.3	1.7	2.6	2.1	6.0	5.8	8.0	2.0
CaO	52.5	54.3	.32	4.2	3.1	.63	7.7	7.6	4.5	4.3
Na_2O	.60	.09	.09	3.0	7.9	4.2	4.0	4.1	3.8	6.5
K_2O	.10	.21	.32	3.8	1.2	5.2	.50	.95	1.5	.30
H_2O^-	.06	.07	.45	.46	.61	.48	.63	.91	.54	.53
H_2O^+	.47	.88	1.4	1.9	1.2	2.1	4.0	3.1	3.2	1.3
TiO_2	.00	.00	.14	.41	.55	.44	.88	1.7	.94	1.1
P_2O_5	.02	.00	.02	.12	.15	.12	.58	.41	.31	.39
MnO	.00	.00	.02	.28	.08	.15	.22	.25	.16	.31
CO_2	42.5	40.6	<.05	5.5	.11	<.05	2.4	2.2	<.05	.10
Volatiles other than H_2O and CO_2			5.4							
Total	100	99.21	99	100	100	100	99	99	100	100

Molecular norms

Qz	91.3		0.2	15.5				8.7
or	2.0		7.1	30.9	3.0	5.7	8.9	1.8
ab	.8		67.4	35.7	34.3	35.3	32.3	55.4
an	1.6		8.8	2.4	19.5	21.5	20.1	9.8
C	1.4			.9	1.8	.3	2.3	
Salic	97.1		83.6	85.4	58.6	62.8	63.6	75.7
wo			2.1					3.5
di			3.9					7.0
en	0.8		6.5	5.3	9.2	6.3	18.5	5.0
fs			.6	3.7	7.9	4.6	5.6	6.7
fo					4.1	5.8	1.0	
fa					3.9	4.7	.4	
mt			4.4	2.5	3.4	3.4	5.0	4.5
il	.3		1.1	.8	1.7	3.3	1.8	2.1
ap	.1		.4	.3	1.4	1.0	.7	1.0
cc			.3		5.5	5.1	.1	.2
hm	.3							
Femic	1.5		15.3	12.6	37.1	34.2	33.1	23.0

1. Golden Horn Limestone Lentil; collected south of Skolai Creek at approximate elevation of 5,000 feet; sec. 34, T. 2 S., R. 17 E., Copper River base line; McCarthy C-4 quadrangle.
2. Golden Horn Limestone Lentil; collected south of Skolai Creek at approximate elevation of 4,700 feet; sec. 27, T. 2 S., R. 17 E., Copper River base line; McCarthy C-4 quadrangle.
3. Slate, Hasen Creek Formation; collected from tributary creek to the Chitistone River on northwestern side at approximate elevation of 4,500 feet; sec. 14, T. 4 S., R. 17 E., Copper River base line; McCarthy C-4 quadrangle.
4. Hornfels, Hasen Creek Formation; collected north of the Chitistone River at approximate elevation of 4,700 feet on the Goat Trail; sec. 5, T. 4 S., R. 18 E., Copper River base line; McCarthy C-4 quadrangle.
5. Strongly altered volcanic graywacke, volcaniclastic member of the Station Creek Formation; collected from fault slice of Station Creek Formation (too small to show on pl. 1) in Skolai Creek at approximate elevation of 5,050 feet; sec. 27, T. 2 S., R. 17 E., Copper River base line; McCarthy C-4 quadrangle.
6. Metavolcanic rock, volcaniclastic member of the Station Creek Formation; collected north of hill 3,822 between the Goat Trail and Chitistone River; sec. 8, T. 4 S., R. 18. E., Copper River base line; McCarthy C-4 quadrangle.
7. Porphyritic basalt, volcanic flow member of the Station Creek Formation; collected above Chitistone Glacier at approximate elevation of 3,900 feet; sec. 9, T. 4 S., R. 18 E., Copper River base line; McCarthy C-4 quadrangle.
8. Amygdaloidal pillow basalt, volcanic flow member of the Station Creek Formation; collected on north side of Chitistone Glacier 2,000 feet west of sample number 7 at approximate elevation of 3,600 feet; sec. 9, T. 4 S., R. 18 E., Copper River base line; McCarthy C-4 quadrangle.
9. Porphyritic basaltic andesite, volcanic flow member of the Station Creek Formation; collected on ridge between Toby Creek and Glacier Creek at approximate elevation of 8,500 feet; sec. 26, T. 5 S., R. 18 E., Copper River base line; McCarthy B-4 quadrangle.
10. Porphyritic andesite, volcanic flow member of the Station Creek Formation; collected in 1962 by George Plafker south of Chitistone Glacier at approximate elevation of 4,700 feet, sec. 16, T. 4 S., R. 18 E., Copper River base line; McCarthy C-4 quadrangle.

TABLE 2.—*Semiquantitative spectrographic analyses of rocks from the Skolai Group*

[Results are reported in percent to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1 . . . , which represent approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results will include the quantitative value for about 30 percent of the results. (...)=not looked for; the following elements were looked for but not detected: Ag, As, An, Bi, Cd, Ge, Hf, Hg, In, Li, Pd, Pt, Re, Sb, Sn, Ta, Te, Th, U, W, Zn, Pr, Sm, and Eu. Spectrographic analyses: samples 1–6 by Marcelyn Cremer; samples 7–10 by Chris Heropoulos. Sample descriptions are given in table 1]

	Hasen Creek Formation				Station Creek Formation					
	Golden Horn Limestone Lentil		Permian(?) sedimentary rocks		Volcaniclastic member			Volcanic flow member		
Sample	1	2	3	4	5	6	7	8	9	10
Laboratory No.	65M-213	65M-901	65M-897	65M-895	65M-899	65M-896	M104877W	M104876W	M104879W	M104878W
Field No.	62AMk-215	62AMk-214	62AMk-163	62AMk-117	62AMk-247	62AMk-215	62AMk-151	62AMk-150	67ASj-288B	67Apr-4a
B	...	...	0.002	0.002	...	...	...	...	...	...
Ba	0.005	0.002	.1	.07	0.03	0.3	0.015	0.05	0.07	0.02
Be	...	...	...	.0005	.00015	.0003	...	...	...	.0003
Ce	(1)	(1)	...	.02	.015	...	...	...	...	...
Co	...	...	...	...	.001	...	.005	.005	.005	.0002
Cr	.0005	.0007	.001	.001	.0005	.0007	.01	.007	.02	...
Cu	.0001	.0001	.0003	.003	.003	.0005	.007	.015	.02	.003
Ga	...	...	...	.002	.002	.002	.002	.002	.0015	.003
La	...	...	...	.01	.003	.003	...	...	...	...
Mo	...	...	.0003	...	...	...	...	...	...	.0005
Nb	...	...	...	.005	.0015	.002	.0015	.001	...	.002
Ni	.0005	...	.001	.001	.0005	.001	.007	.005	.01	...
Pb	...	...	...	.007	...	.002	...	...	...	...
Sc	.0007	...	...	.0007	.0015	.001	.003	.005	.003	.005
Sr	.015	.015	.007	.01	.015	.07	.03	.1	.1	.03
V	.001	.005	.007	.003	.015	.003	.03	.03	.03	...
Y	.001	.0015	...	.01	.07	.007	.005	.005	.003	.01
Yb	.0001	.00015	...	.001	.0007	.0007	.0005	.0005	.0003	.001
Zr	...	...	.003	.007	.05	.03	.02	.02	.01	.07
Nd	(1)	(1)	...	.015	...	...	...	...	...	...

[1] High Ca interferes with the most sensitive Ce and Nd determinations.

In the lower, coarser grained beds, bedding is poorly developed and difficult to see in many outcrops, but beds appear to be from tens to hundreds of feet thick. In general, the thicker the bed, the larger and more angular are its clasts, the poorer is its sorting, the fewer are its internal laminations or hints of grading, and the more massive are its outcrops. Pillow breccias and broken pillow breccias are rudely bimodal; pillows and pillow fragments form the coarser grained fraction and debris generally smaller than 1 cm forms the finer grained fraction. Other volcaniclastic beds show an unbroken grain size range from coarsest to finest.

The upper, finer grained beds in the member range from less than 1 cm to 15 cm in thickness with an average close to 10 cm. Sorting is poor. Graded bedding, load casts, and flame structures are common. Jointing at a high angle to bedding, which is common in these brittle rocks, has resulted in the formation of sharp-edged, fist-sized rhombs.

The volcaniclastic rocks range widely in color. Their weathered surfaces are predominantly dark green and less commonly dark shades of blue and gray. Their freshly broken surfaces typically are shades of black, dark gray, or green. Thin-bedded rocks in the upper part of the member are predominantly light apple green to dark green when fresh; their weathered surfaces are darker.

PETROGRAPHY

A narrow range of mafic to intermediate compositions is represented in the volcaniclastic rocks, but the clasts include a wide variety of volcanic textures. All clasts are identical in composition and texture to lavas in the volcanic flow member of this formation, and thus the clasts and lavas clearly had the same source. The largest blocks seen in breccias were pillows and broken pillows close to a foot across; most clasts are much smaller. Figure 4 shows in thin section a coarse tuff-breccia that is less metamorphosed than most but otherwise typical. Glassy clasts have recrystallized to mosaics of xenoblastic quartz and feldspar less than 75 microns across. Minute flakes of pleochroic green chlorite have recrystallized along concentric perlitic cracks; similar chlorite fills stretched vesicles in pumice lapilli and preserves original flow structures. Optically the chlorite is length slow, has a maximum birefringence of 0.006, and has anomalous blue extinction. The apple-green chlorite contrasts with the surrounding clear recrystallized glassy part of the lapilli. The glassy groundmasses of lapilli have recrystallized to very fine grained mosaics of quartz and feldspar, as in the perlite fragments. A few pumice lapilli contain euhedral plagioclase phenocrysts as large as 2 mm, but like the plagioclase groundmass grains, they are now mostly cloudy polysynthetically

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FIGURE 4.—Coarse tuff-breccia from the volcaniclastic member of the Station Creek Formation. R, recrystallized glassy clasts with perlitic cracks; V, pumice lapilli with abundant chlorite-filled vesicles; P, individual murky plagioclase phenocrysts.

twinned metamorphic albite. The plagioclase grains that survived metamorphism are andesine.

Volcanic rock fragments represent a wide variety of textures typical of flows in the volcanic flow member of this formation. The number of phenocrysts of plagioclase and mafic minerals varies widely from rock to rock, but generally the phenocrysts constitute from 0 to 15 percent of a typical rock. The scarce unaltered mafic phenocrysts consist of euhedral subcalcic augite and needles of brown hornblende. Most mafic phenocrysts, however, have been replaced by pseudomorphous aggregates of chlorite, epidote, and calcite. Groundmasses have generally recrystallized sufficiently to mask original textures, but small twinned laths up to 0.3 mm long of albite pseudomorphous after original plagioclase microlites remain. The rest of the present groundmass is a cloudy xenoblastic aggregate of low-grade metamorphic minerals varying from specimen to specimen, but including albite, chlorite, sphene, calcite, pumpellyite, prehnite, and epidote.

The fine-grained graywacke matrix of these coarse-grained volcaniclastic rocks resembles the groundmass of the volcanic clasts. Metamorphic recrystallization has blurred the distinction between the fine-grained matrix of the beds and the groundmasses of clasts within the beds. Margins of grains are often made fuzzy by the growth of new minerals. The graywacke matrix has recrystallized to the same low-grade xenoblastic aggregate of metamorphic minerals as has the groundmass of the clasts.

Fine-grained and thin-bedded graywacke, volcanic sandstone, and volcanilutite predominate in the upper part of this member, but there is some interbedded tuff-breccia.

Thin sections of graywacke and sandstone show angular detrital coarse sand- to silt-sized grains of plagioclase, volcanic rock fragments, strained quartz grains, and subordinate mafic grains. Clasts are set in a fine shreddy almost submicroscopic mosaic of metamorphic albite, chlorite, epidote, quartz, sericite, calcite, pumpellyite, and opaques derived from the original matrix. Volcanic rock fragments are mashed and molded around other grains, further obscuring original textures. Crystal clasts typically display angular, broken outlines, whereas the crystals in tuff-breccias and coarser grained rocks are less modified by attrition and generally have original crystal faces. More than 95 percent of the grains are volcanic in origin, and their composition is similar to that of the volcanic and volcaniclastic rocks in the rest of the formation.

Distinctive red beds of coarse breccia and tuff-breccia make up an uncommon but striking rock type in the member. All the feldspars and much of the groundmass of volcanic rock fragments are bright red, while the intergranular matrix is dark. Microscopic examination shows dust-sized flakes of a translucent red mineral (hematite?) to be responsible for the red color. Potassium feldspar was found in these rocks, both microscopically and by staining. These red tuff-breccias may be the same as the latite tuffs of Muller (Muller, 1967, p. 34).

The volcanisiltstones and lutites are hard, brittle rocks in shades of green which resemble cherts in outcrop. Close examination shows laminations and local crossbedding. Under the microscope they are seen to be made of angular silt-sized and finer volcanically derived grains set in a dark-colored nearly unidentifiable paste. This matrix-paste was formed by metamorphic recrystallization of the original clay-sized fraction and consists of formless clots of both highly birefringent and opaque minerals less than 150 microns across. Individual clots are composed of many smaller xenoblastic grains, less than 10 microns across. While recrystallization resulted in increased grain size, sedimentary features were preserved because of (1) a difference in proportions of epidote, sphene, chlorite, and other metamorphic minerals from lamina to lamina and (2) a differential increase in grain size from lamina to lamina.

Metamorphic grade increases from northeast to southwest as shown on plate 1. Reconnaissance of nearby areas showed that the increase is part of a general increase in metamorphic grade eastward toward the Canadian border. This increase is marked by (1) greater recrystallization, especially of the finer grained constituents such as groundmasses, (2) an increase in size of metamorphic minerals, (3) an appearance of greenschist facies minerals, and (4) a decrease in amount of pumpellyite-prehnite facies minerals. The main metamorphic effects are thermal; shearing and strong folding are minor.

AGE AND CORRELATION

No fossils were found in the Station Creek Formation. The formation is considered to be Permian(?) in age because of its proximity to, and structural continuity with, fossiliferous Early Permian rocks of the overlying Hasen Creek Formation and because of its structural discontinuity with and difference in metamorphic grade from subjacent rocks, which are largely or entirely Mississippian in age.

Probable correlatives of the Station Creek Formation are widespread in nearby parts of the Wrangell Mountains and in the Yukon Territory. They have been described mainly by Moffit (1938, p. 29–37; 1954, p. 103–118), Capps (1916, p. 33–47), and Muller (1967, p. 34–43). In most of these reports, descriptions of the Station Creek rocks are grouped with those of the overlying fossiliferous Permian rocks correlative with our Hasen Creek Formation.

HASEN CREEK FORMATION

The Hasen Creek Formation is here named for Hasen Creek, a southeastward flowing tributary of the Chitistone River in the southeastern part of the McCarthy C–4 quadrangle. The formation's type area is designated as the valley walls of Hasen Creek in secs. 11 and 12, T. 4 S., R. 17 E., Copper River base line and meridian (fig. 1). In the northern part of the C–4 quadrangle, the formation contains a conspicuous limestone lens that we have named the Golden Horn Limestone Lentil.

DISTRIBUTION AND GENERAL DESCRIPTION

The Hasen Creek Formation is well exposed on the gentle slopes above treeline southwest of the Golden Horn toward Skolai Creek in the McCarthy C–4 quadrangle and along Hasen Creek. Elsewhere, most gentle slopes are dip slopes and do not result in good exposures, and thus extensive sections of the formation are restricted to steep-walled glaciated canyons. The formation consists of a heterogeneous mixture of thin-bedded chert, black shale, sandstone, carbonaceous bioclastic limestone, and minor conglomerate; the amount of volcanic material in the formation is low. Moffit (1938) described interbedded basalt flows in his measured sections of Permian rocks equivalent to the Skolai Group. We believe, however, that these basalts are either below our Hasen Creek Formation or are fine-grained gabbro sills, which are easily mistaken for basalt flows. The Hasen Creek Formation is thickest near Skolai Creek, where excluding the Golden Horn Limestone Lentil, it is nearly 900 feet thick (fig. 2).

The contact of the Hasen Creek Formation with the underlying Station Creek Formation is gradational over a few hundred feet. The typically thin-bedded volcanilutites and volcanisiltstones of the upper part of the Station Creek Formation are interbedded with upwardly increasing amounts of nonvolcanic shales and sandstones. In most places this change is marked by the green, hard, flinty, volcanilutites below and the soft, fissile black shales, slates, or, locally, thin limestone beds above. North of upper Skolai Creek, the contact was drawn at the base of a sequence of thin limestone beds.

The Hasen Creek Formation is overlain with slight angular discordance mainly by the Nikolai Greenstone or with strong angular discordance by Tertiary rocks including basal parts of the Wrangell Lava and the Frederika Formation (MacKevett, 1969). Two localities were found where Hasen Creek rocks are overlain by Middle Triassic sedimentary rocks. At one of these, north of Skolai Creek (fig. 1), the Golden Horn Limestone Lentil of the formation underlies siltstone and shale that contain abundant pelecypods identified as *Daonella*, a Middle Triassic index fossil (MacKevett and others, 1964; MacKevett, 1969). At the other, north of Toby Creek in the B–4 quadrangle (fig. 1), thin-bedded Hasen Creek rocks are overlain by lithologically similar rocks that contain fragments of Middle Triassic pelecypods and ammonites (identified by N. J. Silberling, written commun., 1968).

Actual contacts are obscure at both of these localities, but differences in attitudes of nearby bedding indicate slight unconformities. The Hasen Creek Formation is cut by discordant and concordant gabbro masses and is locally overlain by Quaternary surficial deposits.

The angular discordance between the Hasen Creek Formation and the Nikolai Greenstone is about 20° in the vicinity of the type area on Hasen Creek, but it decreases southward. Relief on the surface of the unconformity is low, and in many places bedding in the Hasen Creek Formation is parallel to flows in the greenstone. Broad channels more than 100 feet deep formed along the contact on Glacier Creek and elsewhere, but the thickness of strata removed by erosion from the Hasen Creek Formation before deposition of the Nikolai Greenstone is unknown. The formation is, however, 250 feet thinner near Canyon Creek than near Skolai Creek, indicating more strata were removed to the south.

LITHOLOGY

Cherts are most abundant in the upper parts of the Hasen Creek Formation. Commonly their fresh surfaces are black, red, or green. Locally, deep-colored cherts are leached to a chalky white and contain iron-stained fractures. Interbeds of black shale which range in thickness from 3 inches to selvages are associated with most chert sequences. Individual chert beds are between 1 and 6 inches thick and average about 3 inches. Pinch and swell structure is generally absent; thus the thickness of individual beds remains constant over long distances.

Local folding and crumpling of these thin, brittle, and incompetent beds is widespread. The folds are open to isoclinal and overturned with amplitudes of 2–20 feet. Crumpling has so laced these rocks with fractures at high angles to bedding that collecting hand specimens is difficult. Despite its fractured nature, however, chert is generally well exposed.

Thin sections of chert show a poorly crystalline matrix composed of a fine aggregate of quartz and chalcedony. Set in this matrix are varying amounts of black opaque iron-oxide dust, silica-filled radiolarian tests, rod-shaped spicules less than 50 microns long, detrital muscovite and chlorite flakes less than 100 microns long, and rare angular detrital grains of quartz and feldspar that are of fine sand size.

Some chert beds contain fine laminations between 1 mm and 1 cm thick that reflect differences in composition. Fractures, which are about 1 mm across, are filled with feathery quartz, iron oxides, and clinozoisite.

A wide range of detrital clastic rocks is represented in the sedimentary rock member, but impure arkose and subgraywackes predominate;

conglomerate is locally abundant. Outcrops are dark shades of green and gray and are more rounded than those of other rocks in the Hasen Creek. Crossbedding and graded bedding are common. Some coarse sandstones are flaggy. Common types of clasts include lithic fragments (nonvolcanic lithic fragments are far more abundant than volcanic ones), quartz, plagioclase, potassium feldspar (less than 20 percent), conglomerate, and micas (chiefly biotite). Some coarse sandstone, pebble conglomerate, and cobble beds are cannibalistic and are composed almost entirely of chert fragments, shale chips, detrital clastic rocks, and limestone clasts derived from underlying beds. The subgraywackes, as compared with the arkoses, are darker, have only a few percent potassium feldspar, and are generally finer grained.

The shales are soft, fissile black rocks which crop out poorly. Areas underlain by shales form gentle slopes covered with a thick mantle of small weathered chips. One or two sets of systematic, iron-stained joints, spaced a few inches apart, cut the shales. Systematic joint sets usually form at high angles to bedding, and nonsystematic sets at low angles.

The limestone beds range in thickness from 6 inches to 2 feet. Even though they are dark gray or black, they stand out from the shales and cherts with which they are interbedded because they are more resistant to physical disintegration. The limestone beds form local marker beds for mapping small structures.

Mixed-fossil wackestone is the dominant textural type (terminology of Dunham, 1962). Well-worn fossil fragments constitute from 20 to 60 percent of the rock and are supported by mud. The most abundant bioclast type consists of well-worn and often broken disarticulated crinoid stem plates. Less abundant are broken and worn disarticulated brachiopod shells. Small solitary corals are uncommon, but some have resisted crushing and breaking during transport and are found relatively well preserved. Bryozoan fragments are nearly absent.

Originally, the supporting matrix was made of fine lime mud mixed with varying amounts of clay minerals and scant detrital quartz and feldspar; however, most of the lime mud has recrystallized to coarser grained calcite or has been replaced by dolomite. Dolomite typically forms euhedral rhombs, close to 250 microns across, and locally replaces up to 90 percent of the original lime mud. Ghosts of clast-matrix boundaries remain in dolomite rhombs which grew across these boundaries. Dolomite preferentially replaced the fine-grained matrix of wackestones; dolomite rhombs are rarely found wholly within calcite bioclasts.

GOLDEN HORN LIMESTONE LENTIL

DISTRIBUTION AND GENERAL DESCRIPTION

The bold yellow- and red-stained cliffs of massive bioclastic Permian limestone on both sides of Skolai Creek in the McCarthy C-4 quadrangle attracted the attention of early prospectors, who named the most prominent peak the Golden Horn (fig. 3). The name was first used informally as a geologic name for these limestones by Moffit (1938). We propose the formal name Golden Horn Limestone Lentil for this part of the Hasen Creek Formation. The type area is designated as the area on the north side of Skolai Creek extending westward from the Golden Horn to Tinplate Hill. (On the U.S. Geological Survey's 1959 topographic map edition of the McCarthy C-4 quadrangle, the Golden Horn is incorrectly shown as peak 7285, or triangulation station Coal, in sec. 13, T. 2 S., R. 17 E. The correct identification of the Golden Horn is peak 6365 in sec. 23, T. 2 S., R. 17 E.)

The Golden Horn Limestone Lentil forms high cliffs and massive bold outcrops with local sinkholes. Because of the high cliffs, most traverses must be made with care down gullies. At first glance, the beds appear continuous, but careful tracing along cliff faces shows that individual beds having centers as thick as 10 feet pinch out over a distance of several hundred yards.

The Golden Horn Limestone Lentil is nearly 800 feet thick at its thickest exposures, but an unknown thickness of limestone beds has been removed during two periods of erosion. The limestone lentil commonly forms the stratigraphically highest unit in the Hasen Creek Formation, although locally it is overlain by other rocks of the formation. At most places the lentil overlies rocks typical of the Hasen Creek Formation. Contacts between the two units are concordant and sharp, but the advent of carbonate deposition is signaled by several limestone beds in the Hasen Creek Formation near the contact. Crudely stratiform gabbro masses separate the lentil from underlying Hasen Creek rocks in part of the mountainous terrain south of Skolai Creek, and gabbro locally cuts the lentil. Near the terminus of Hole in the Wall Glacier, the limestone lentil conformably overlies rocks of the Station Creek Formation.

Throughout most of its range the lentil is unconformably overlain by rocks of the Nikolai Greenstone, Wrangell Lava, or Frederika Formation. Less extensively it is overlain with probably slight unconformity by Middle Triassic *Daonella* beds or is overlain conformably by other Hasen Creek rocks. Quaternary surficial deposits mantle the lentil at a few places.

PETROGRAPHY

The limestone lentil consists of bioclastic grainstone and packstone with subordinate wackestone and calcite cemented arkoses. The color of the fresh limestone ranges from pure white to light blue gray; however, trace amounts of iron-bearing impurities stain the weathered surfaces bright shades of rust red and yellow. The grainstones are generally lighter colored than the wackestones.

Coarse bioclastic grainstones and packstones (both encrinite) are the most common rock types in the lentil. Slightly worn coarse bioclasts form a self-supporting network, partially infilled with fine lime mud and detrital sand grains. The most abundant bioclast type consists of disarticulated crinoid stem plates as large as one-half inch in diameter; they make up more than 75 percent of the clasts in some beds. The stems are slightly worn and surface ornamentation is blurred; overgrowths of clear calcite (rim cement) with the same crystallographic orientation as the stems and embayed contacts due to press solution are common.

Brachiopod shells are almost absent locally but range widely in abundance, in places making up more than 50 percent of the encrinites. Most shells are unbroken, but many are disarticulated and abraded; all are slightly worn. The shells are not in growth positions, but evidently have been transported only short distances.

Crushed and macerated bryozoan fragments constitute one-third to one-half of the encrinites. Broken and worn tests of ostracodes and Foraminifera are found in some of the limestones.

Clear, rounded quartz granules and small pebbles form thin lenses within grainstone beds. Some quartz grains were deposited in the upturned valves of disarticulated brachiopod valves. Frequently quartz sands form geopetal deposits in the overturned disarticulated brachiopod valves.

The matrix in the packstone consists of lime mud particles a few microns across. The mud collected in the disarticulated, upturned brachiopod valves or formed floored interstices between other grains.

Dolomite rhombs form 1–2 percent of the encrinites. The rhombs are approximately 150 microns across and preferentially replaced lime mud or filled chambers of Foraminifera. Dolomite rhombs also grew in crinoid stems and brachiopod shells but are less common there than in lime muds. Where the rhombs cross boundaries between mud and encrinite clasts, the boundary remains as a ghost with clear dolomite on the clast side and murky dolomite on the mud side. This relation shows that the dolomite grew after cementation.

The lenticullar shape of beds, paucity of lime mud, worn bioclasts not in growth position, and coarseness of sediment indicate that the debris forming the grainstone and packstone was transported by high-energy currents and deposited possibly in part in tidal channels.

The wackestone is subordinate to grainstone and packstone. Frequently the abundant fossils in the wackestone are in growth positions or nearly so. Crinoid stems are slightly disarticulated but still touching, like pushed-over stacks of coins. Complete bryozoan fronds are draped where they fell over the crinoids. The most minute details of ornamentation are still preserved.

Detrital grains of quartz and calcite overgrowths are absent in the wackestone. The matrix, which may make up as much as 60 percent of the rock, consists of fine lime mud.

The preservation of delicate fossils in growth positions and the abundance of lime mud is evidence for noncurrent deposition of wackestones in the quiet waters of interchannel areas.

AGE AND CORRELATION

The fossil collections are from both the richly fossiliferous Golden Horn Limestone Lentil and from other strata in the formation. The collections were studied by R. E. Grant in consultation with E. L. Yochelson and J. T. Dutro, Jr. (written commun., 1966). According to Grant,

> the fauna is not differentiated by rock type, at least as concerns genera that might be useful for correlation. Only a few genera of brachiopods are present, and they are the ones normally found in the Arctic Permian. Correlation must depend more on the absence of certain elements than on presence of common Arctic genera. The brachiopod fauna contains Permian elements, but none that definitely indicates a Late Permian age. Therefore, Early Permian is suggested by default. Yochelson examined snails in sample 62Apr–11D (USGS 22379–PC), which he identified as species of *Straparolus* (*Euomphalus*). They are not sufficiently well preserved for specific identification, but they seem to resemble *S.* (*E.*) *cornudanus* (*Shumard*) of Wolfcampian age more closely than *S.* (*E.*) *kaibabensis* of late Leonard and Word age. This tentative opinion supports the essentially negative evidence of the brachiopods that the collections are Early Permian.

Grant's faunal lists of the collections follow. All collections are from the McCarthy C–4 quadrangle, and their locations are keyed alphabetically to plate 1. A few collections that appear to contain similar fauna were made in the B–4 quadrangle.

(A) USGS 22371–PC (62AMk–218). Golden Horn Limestone Lentil; 3.2 miles S. 1° W. of triangulation Coal. Lat 61°39′00″, long 142°15′18″.

crinoid columnals, indet.
Bryozoa, undet.
Spiriferella sp.

(B) USGS 22372–PC (62AMk–231A). Golden Horn Limestone Lentil, south of Skolai Creek; 0.55 mile N. 21° W. of triangulation Fulcrum. Lat. 61°40′6″, long 142°21′51″.

crinoid columnals, indet.
horn corals, undet.
abundant bryozoans, undet.
Horridonia sp.
Spiriferella sp.

(C) USGS 22373–PC (62AMk–252). Hasen Creek Formation, limestones interbedded with shales, east of the Nizina Glacier and south of Skolai Creek; 0.50 mile S. 42° W. of triangulation Fulcrum. Lat 61°38′26″, long 142°23′36″.

crinoid columnals, indet.
Horridonia sp.
productoid fragment?, indet.
Spiriferella sp.

(D) USGS 22374–PC (62Bg–238a). Golden Horn Limestone Lentil, northeastern part of quadrangle south of Skolai Creek; 3.56 miles S. 9° E. of triangulation Coal. Lat 61°38′36″, long 142°14′6″.

crinoid columnals, indet.
Bryozoa, undet.

(E) USGS 22375–PC (62Bg–242F). Golden Horn Limestone Lentil, northeastern part of quadrangle south of Skolai Creek; 3.50 miles S. 15° E. of triangulation Coal. Lat 61°38′42″, long 142°13′45″.

crinoid columnals, indet.
Spiriferella sp.

(F) USGS 22376–PC (62Bg–267a). Hasen Creek Formation, east of Nizina Glacier and north of Moonshine Creek; 2.78 miles S. 83° W. of triangulation Foothill. Lat 61°37′57″, long 142°24′54″.

crinoid columnals, indet.
Bryozoa, undet.
Anidanthus? sp.
Horridonia sp.
"*Spirifer*" sp.
Spiriferella sp.

(G) USGS 22377–PC (62Bg–268a). Hasen Creek Formation; 200 feet north of 62Bg–267a.

cf. *Chaoiella*? sp.
Horridonia sp.
Spiriferella sp.

(H) USGS 22378–PC (62Bg–270F). Hasen Creek Formation, west-central part of quadrangle east of the Nizina Glacier. Lat 61°38′9″, long 142°24′55″.

horn corals, undet.
Anidanthus? sp.
Horridonia sp.
Choristites? sp.
Neospirifer sp.
Spiriferella sp.

(I) USGS 22379–PC (62APr–11D). Hasen Creek Formation, limestones and shales near south border of quadrangle north of the Chitistone River; 4.3 miles N. 76½° W. of southeast corner of quadrangle Lat 61°31′1″, long 142°15′56″.

Liosotella sp.
Spiriferella? sp.
small spiriferoid, indet.
Straparolus (*Euomphalus*) sp.

(J) USGS 22380–PC (62APr–11E). Hasen Creek Formation, slabby limestone about 200 feet S. 9° E. of 62APr–11D and probably lower stratigraphically.

horn coral, undet.
crinoid columnals, indet.
Horridonia, small sp. (or *Liosotella pseudohorrida* (Wiman)) productoid fragment, indet.
Choristites sp. (or smoothly weathered *Spiriferella* sp.)
Odontospirifer? sp.
Spiriferella sp.

(K) USGS 22381–PC (62APr–19G). Hasen Creek Formation, northeastern part of quadrangle; 1.47 miles N. 36½° W. from triangulation Coal. Lat 61°42′39″, long 142°16′54″.

crinoid columnals, indet.
Bryozoa, undet.
productoid fragment (*Krotovia?* or *Cancrinella?*)

(L) USGS 22382–PC (62APr–25E). Golden Horn Limestone Lentil, near Golden Horn; 0.75 mile S. 74½° W. from triangulation Coal. Lat 61°41′27″, long 142°16′15″.

crinoid columnals, indet.
horn corals, undet.
cf. *Chaoiella* sp.
Cleiothyridina sp.
Horridonia sp.
Rhynchopora sp.
Neospirifer sp.
spiriferoid brachiopod, indet.

(M) USGS 22383–PC (62APr–35D). Hasen Creek Formation, limestone from west-central part of quadrangle east of Nizina Glacier; 1.71 miles S. 29° E. of triangulation Foothill. Lat 61°36′54″, long. 142°22′23″.

crinoid columnals, indet.
Bryozoa, undet.

(N) USGS 22384–PC (62APr–56G). Hasen Creek Formation float, north-central part of quadrangle; 1.6 miles S. 60° W. of triangulation Coal.

crinoid columnals, indet.
Bryozoa, undet.
Horridonia sp.
"*Spirifer*" sp. (of the *S. striatoplicatus* type)
Spiriferella sp. (abundant)

(O) USGS 22385–PC (62APr–68G). Golden Horn Limestone Lentil; 1.65 miles S. 52½° E. from northwest corner of quadrangle. Lat 61°43′57″, long 142°28′30″.

crinoid columnals, indet.
Bryozoa, undet.
productoid fragments (*Chaoiella?* sp.)
Spiriferella sp. (fragments)

(P) USGS 22386–PC (62APr–77D). Hasen Creek Formation, sandstone in prong in Rohn Glacier near northern boundary of quadrangle; 2.43 miles S. 83 E. from northwest corner of quadrangle. Lat 61°44′48″, long 142°25′36″.
- brachiopod fragments (spiriferoid and productoid, indet.)
- pelecypod fragments?, indet.
- gastropod fragments, indet.

(Q) USGS 22387–PC (62APr–79a). Hasen Creek Formation, at elevation 5,100 feet on east side of Golden Horn. Lat 61°41′00″, long 142°16′18″.
- linoproductoid brachiopod fragment, indet.
- pelecypod?, indet.
- gastropod, indet.

Correlatives of the Hasen Creek Formation are widespread in the northern and eastern parts of the Wrangell Mountains, in the eastern Alaska Range, and in the Yukon Territory. They have been described and paleontologically documented by Moffit (1938, p. 29–37; 1954, p. 103–118), Mendenhall (1905, p. 40–47), Capps (1916, p. 33–47), and Muller (1967, p. 33–43).

On the basis of the paleontologic evidence, the Hasen Creek Formation and the Golden Horn Limestone Lentil are considered to be Early Permian.

ORIGIN

During the time in which the Skolai Group was deposited, the sediments changed from deep-water eugeosynclinal volcaniclastic deposits to shallow-water, nonvolcanic fine-grained clastic debris and large crinoid banks.

The lava flows, pillow breccia piles, and thick accumulations of volcaniclastics of the Station Creek Formation formed as a series of local volcanic centers with their associated volcanic dispersal aprons. Most lava in the volcanic flow member, was erupted as a thick series of underwater lava flows with only occasional pillow deposits and volcaniclastic beds, perhaps like the flanks of the Hawaiian Islands today. Polymict volcaniclastic beds in the overlying volcaniclastic member were derived from nearby volcanic sources. They originated as debris washed in from littoral deposits, as turbidity currents, and as submarine landslides. Some of the monolithologic volcaniclastic beds probably formed from lavas erupted in water too shallow to prevent complete vesiculation and explosive underwater eruption, while others probably formed when lava flows on land entered the sea and the resulting rapid quenching broke the lava into sand-sized particles, which were sluiced down the volcano flanks as density currents.

During deposition of the Hasen Creek Formation, volcanic activity either waned or shifted to other sites, and cherts, shales, and nonvolcanic sandstones were deposited.

The Golden Horn Limestone Lentil was formed in areas where water depth was shallow enough, probably near wave base, for the growth of abundant crinoids, bryozoans, and other shelly organisms. The calcareous remains of these organisms were deposited in calcareous sand banks and tidal channel sediments by high-energy currents. The environment of deposition for much of the Golden Horn was probably similar to that for the Turner Valley Formation of Alberta as described by Murray and Lucia (1967).

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