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RECONNAISSANCE INVESTIGATION OF THE LISBURNE GROUP IN THE COBBLESTONE CREEK AREA, CHANDLER LAKE QUADRANGLE, ALASKA

by
Julie A. Dumoulin and Michael T. Whalen

Lower part of the Lisburne Group at May Creek, eastern Chandler Lake Quadrangle. Photo by J.A. Dumoulin.

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RECONNAISSANCE INVESTIGATION OF THE LISBURNE GROUP IN THE COBBLESTONE CREEK AREA, CHANDLER LAKE QUADRANGLE, ALASKA

by
Julie A. Dumoulin[1] and Michael T. Whalen[2]

ABSTRACT

A reconnaissance investigation of the Carboniferous Lisburne Group in the Cobblestone Creek area, Chandler Lake Quadrangle, yields insights into its resource potential and regional relations. Locally porous vuggy dolostone with hydrocarbon reservoir potential occurs in the lower Lisburne in the three most southerly of five thrust sheets, and contains traces of dead oil in two of these sheets. The dolostones are coarse crystalline, commonly cross-bedded, and at least in part of Osagean (late Early Mississippian) age; they have pelmatozoan grainstone protoliths that likely formed in sand shoals of the midramp to inner ramp. Similar, coeval porous dolostones occur in the Lisburne from Skimo Creek to Itkillik Lake, ~70 km west and 10 km east of the Cobblestone Creek area, respectively.

We also examined the uppermost Lisburne Group at several localities in the Cobblestone Creek area, mainly in the northernmost thrust sheet where the rocks are as young as Morrowan (Early Pennsylvanian). Cobblestone sections contain more supportstone than equivalent strata at Skimo Creek, and overlying Permian successions also differ between the two areas. These lithologic contrasts may reflect different rates of tectonically controlled subsidence, and (or) changes in sediment input, along the late Paleozoic continental margin.

INTRODUCTION

The Lisburne Group is a mainly Carboniferous carbonate succession deposited in a range of platform, ramp, slope, and basin environments; it occurs widely in outcrop and subsurface across northern Alaska and contains appreciable oil, gas, and metallic mineral resources (for example, Jameson, 1994; Kelley and Jennings, 2004). In this paper we report preliminary results of a brief examination of the Lisburne Group at several localities in the Cobblestone Creek area, eastern Chandler Lake Quadrangle (fig. 1). Most of the fieldwork for this study occurred during 10 days in late June 2008, preceded by a day of reconnaissance in June 2003. We focused on the lower part of the Lisburne because equivalent strata to the west and east include thick intervals of coarse-crystalline dolostone that are locally porous, contain dead oil, and have good hydrocarbon reservoir potential (Krynine and others, 1950; Armstrong and Mamet, 1977; Dumoulin and others, 1997). We also examined the uppermost Lisburne to determine if the distinctive shale-rich facies found in this stratigraphic position to the west at Skimo Creek (Dumoulin and others, 2008) occurs in the Cobblestone Creek area as well.

KAYAK SHALE AND LISBURNE GROUP (LOWER PART)

In the Cobblestone Creek area, the Lisburne Group occurs in a series of east-trending thrust sheets (Kelley, 1988; Mull and others, 2009). We measured a section of the lower 325 m of the Lisburne Group, including its contact with the underlying Kayak Shale, in cliffs west of the eastern fork of May Creek (loc. 1, fig. 1; figs. 2, 3). This section lies in the third of five thrust sheets mapped in this area by Kelley (1988) and here referred to by increasing number from north to south. We also briefly examined the lower part of the Lisburne Group in the fourth of these thrust sheets along a ridge between Peregrine and Cobblestone creeks, and in the fifth thrust sheet on a ridge ~2 km west of Peregrine Creek (locs. 2, 3, fig. 1). Time did not allow us to investigate the lower Lisburne in the northern two thrust sheets; we focused on the more southerly thrust sheets because porous dolostones were reported from these areas by previous workers (for example, T. Moore, personal commun., 2008). Regional correlations suggest that the Lisburne Group is at least 650–700 m thick in this area, and the Kayak Shale is at least 200 m thick (Dumoulin and others, 1997).

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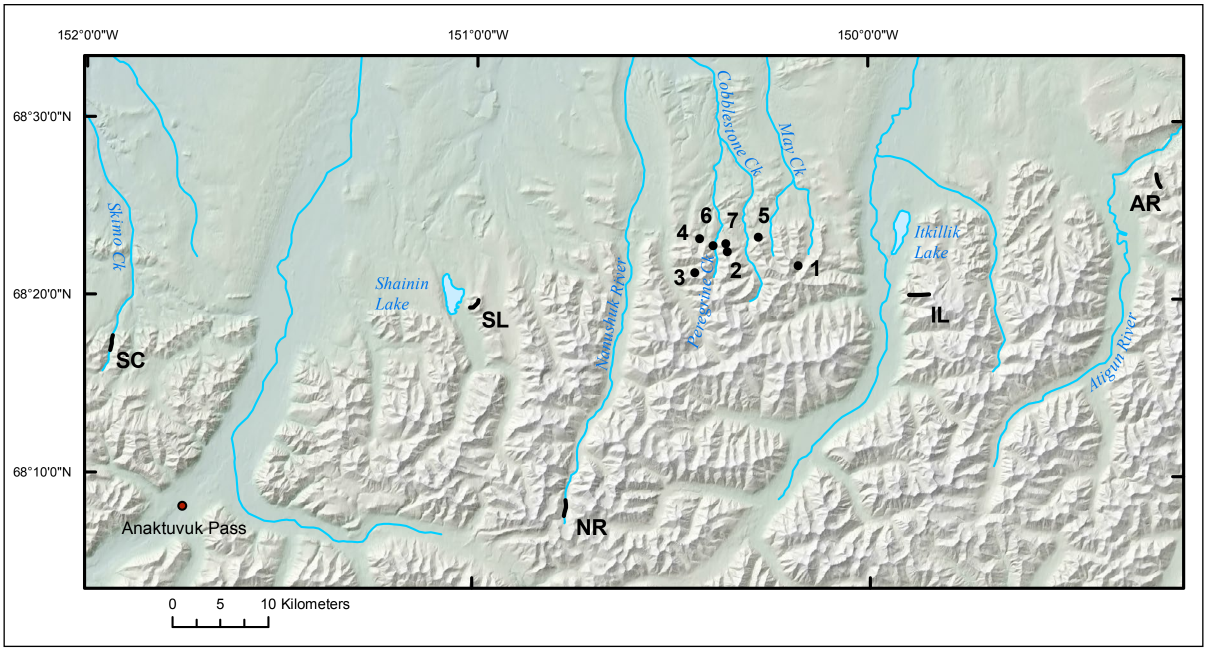

Figure 1. Study area in northern Alaska, showing geographic names and locations of measured sections and lithologic and fossil collections. Numbered dots, localities mentioned in text. AR, Atigun River section of Dumoulin and others (1997); IL, Itkillik Lake section of Armstrong and Mamet (1977); NR, Nanushuk River section of White and Whalen (2006); SC, Skimo Creek section of Dumoulin and others (2008); SL, Shainin Lake section of Dumoulin and others (1997).

May Creek

The Kayak Shale is incompletely exposed at several localities in the May Creek area (Kelley, 1988). Only the upper part of the Kayak crops out in our May Creek section (figs. 2, 4A, 4D), where it consists of at least 25 m of interbedded shale, lime mudstone to wacke-packstone, and subordinate supportstone (packstone and grainstone). Shale is medium gray to black, dominantly calcareous, and forms intervals several meters to a few centimeters thick. Mud-supported, commonly argillaceous carbonate interbeds are pale yellow-brown to yellow-orange weathering, medium to dark gray, and 2 to 20 cm thick (fig. 4B). Grain-supported limestone intervals also weather yellow-orange but are light to medium gray and thin to thick bedded (fig. 4C). Bryozoans predominate in muddier intervals, which range from laminated to partly bioturbated, whereas grainier beds contain mostly pelmatozoan debris. Subordinate components of limestone layers include ostracodes (some articulated), brachiopods, and quartz silt; pyrite locally forms irregular blebs and partly replaces some bioclasts and burrows. We place the contact between the Kayak and the overlying Lisburne Group just above the highest exposure of dark gray shale, but a 20-m-thick covered interval overlying this shale makes exact placement of the contact uncertain. The Kayak has not been dated at May Creek, but ~30 km to the west, at Shainin Lake, it is Kinderhookian (early Early Mississippian) (Dumoulin and others, 1997).

We divide the lower Lisburne Group at May Creek into four informal units, based on outcrop characteristics and general lithofacies (figs. 2, 3). A partly covered zone ~50 m thick represents the basal unit of the Lisburne and is distinguished by pervasive yellow- and orange-weathering colors. Only the upper third of this interval is well exposed; it consists of limestone (locally partly dolomitized) that is similar to the thickest grain-supported beds in the underlying Kayak. The uppermost beds in this interval are a 3-m-thick zone of packstone with 25–30 percent black nodular chert and notable rugose corals overlain by several meters of pelmatozoan–bryozoan supportstone that contains a diverse accessory fauna of brachiopods, ostracods, foraminifers, algae, and gastropods.

The remainder of the lower Lisburne Group at May Creek comprises two units with abundant dolomitic strata separated by a distinctively dark-weathering unit that contains little dolomite (figs. 2, 3). The lower dolomitic unit is ~135 m thick. It consists of meter- to decameter-scale alternations of cliff-forming, light-gray-weathering, mostly chert-free dolomitic supportstone and less resistant, darker-weathering, muddier, cherty limestone (figs. 5A–C). Supportstone forms intervals 5 to >12 m thick, is mostly medium bedded to massive, and parallel and cross laminated, with local trough cross-sets as much as 20 cm thick (fig. 5B). Thin sections show coarse-crystalline dolomite

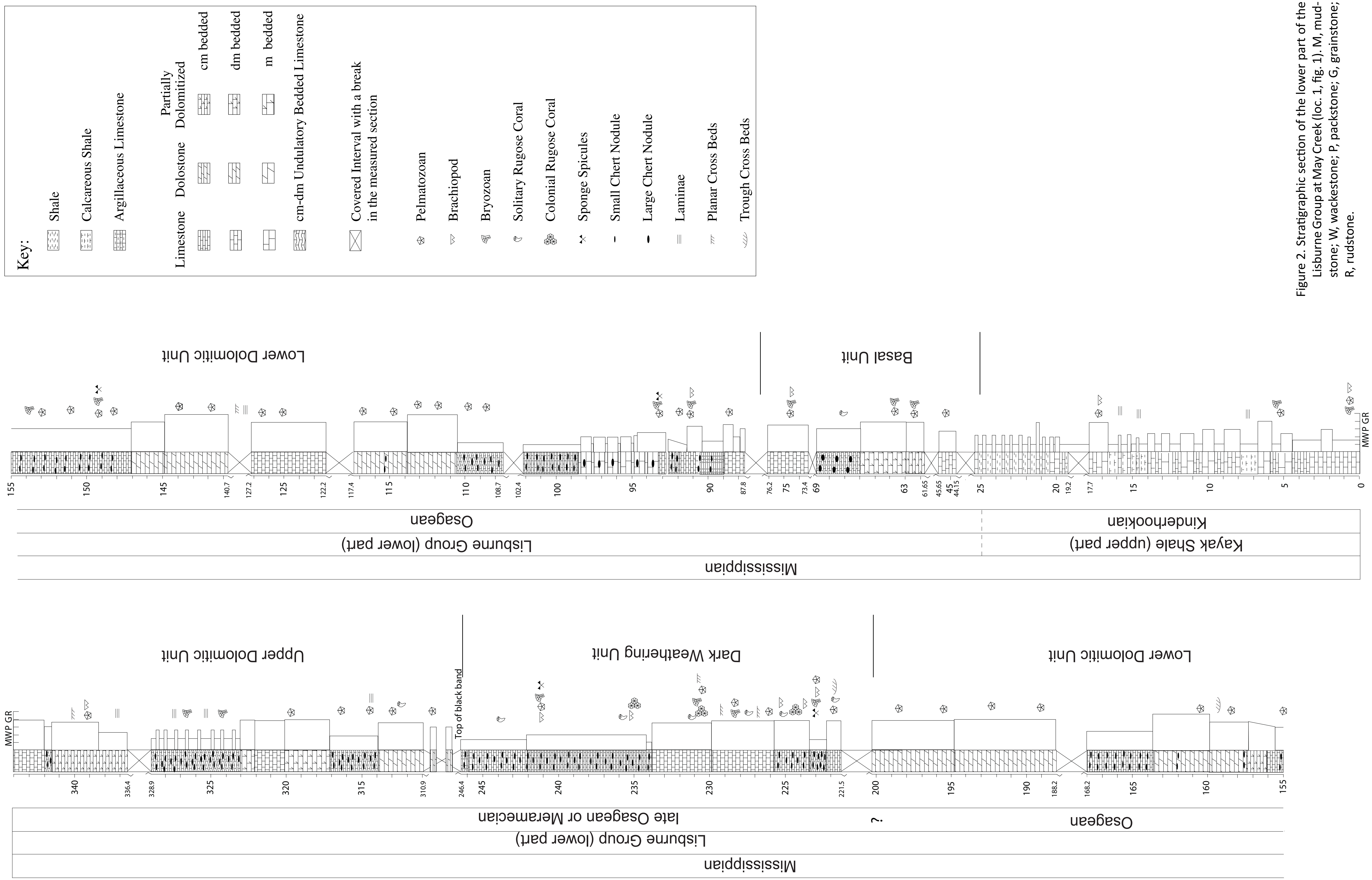

Figure 2. Stratigraphic section of the lower part of the Lisburne Group at May Creek (loc. 1, fig. 1). M, mudstone; W, wackestone; P, packstone; G, grainstone; R, rudstone.

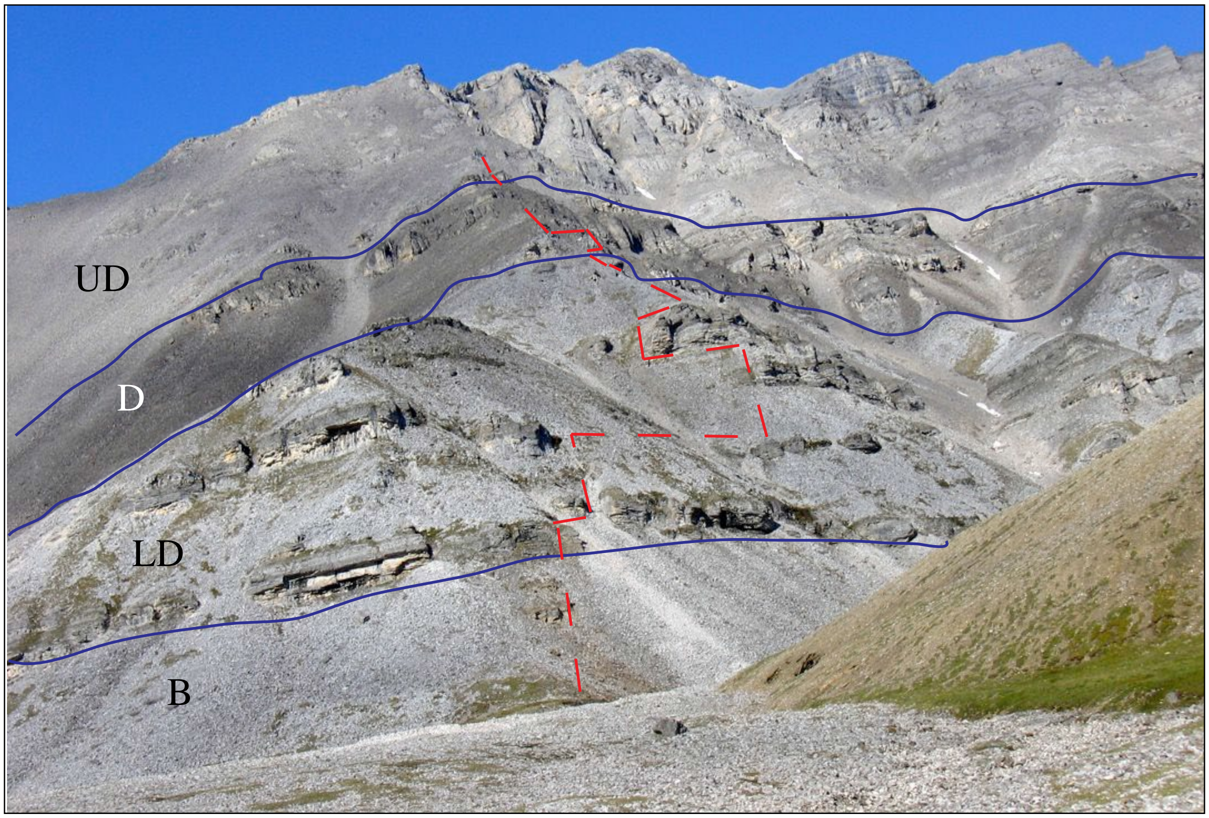

Figure 3. Lower part of the Lisburne Group at May Creek (loc. 1, fig. 1); traverse of measured section (fig. 2) shown by dashed red line. Letters indicate informal units described in text: B, basal unit; LD, lower dolomitic unit; D, dark-weathering unit; UD, upper dolomitic unit. Kayak Shale at base of measured section is out of sight in gully near base of photo.

mosaics (crystals chiefly 0.15–>0.5 mm diameter) that contain relict, partly calcitic pelmatozoan ossicles (to 1 cm diameter) and lesser bryozoan fronds; some beds are completely dolomitized. Textures indicate a pelmatozoan grainstone protolith for these strata. Millimeter-scale vuggy porosity (1–5 percent) occurs in a few samples, but most vugs are filled with sparry calcite. Muddier intervals are lime mudstone to wacke-packstone in 2- to 10-cm-thick, locally nodular beds with 20–50 percent black chert lenses and nodules and minor, disseminated small dolomite rhombs (fig. 5C). Bioclasts in these beds are mainly bryozoan and pelmatozoan fragments, with lesser ostracodes and calcareous sponge spicules.

The dark-weathering unit is ~50 m thick, but only the upper half is exposed. It is mainly laminated to thin-bedded (≤5 cm) lime mudstone to wacke-packstone with 20–60 percent nodular to irregular black chert. Solitary and colonial corals—commonly silicified—are strikingly abundant (fig. 5D) and at least some are in growth position; other components include bryozoan fronds, brachiopods and ostracods (some articulated), pelmatozoan debris, foraminifers, calcareous and siliceous sponge spicules, and minor peloids. Subordinate intervals of cross-laminated pelmatozoan supportstone (cross-beds ~1 cm thick) occur locally.

About 100 m of the upper dolomitic unit were examined in this study; the unit continues upward for at least several decameters on slopes too steep to traverse. The unit resembles the lower dolomitic unit and contains some dolostones with cross-bedding, 5 to 10 percent vuggy porosity (estimated in thin section), and minor scattered grains of glauconite (figs. 5E, F).

Foraminifers indicate that much of the lower Lisburne Group described above is likely Osagean (late Early Mississippian). Supportstone 50 m above the base of the section, near the top of the basal unit, contains an assemblage of early Osagean (late Tournaisian) age; strata correlative with these beds exposed ~0.5 km southeast yield a coeval fauna (table 1). Wacke-packstone ~216 m above the base of the Lisburne near the top of the dark-weathering unit contains numerous foraminifers of likely late Osagean–early Meramecian (early Visean) age (table 1). These ages match well with regional stratigraphic constraints. Conodonts indicate that to the west at Shainin Lake, the basal

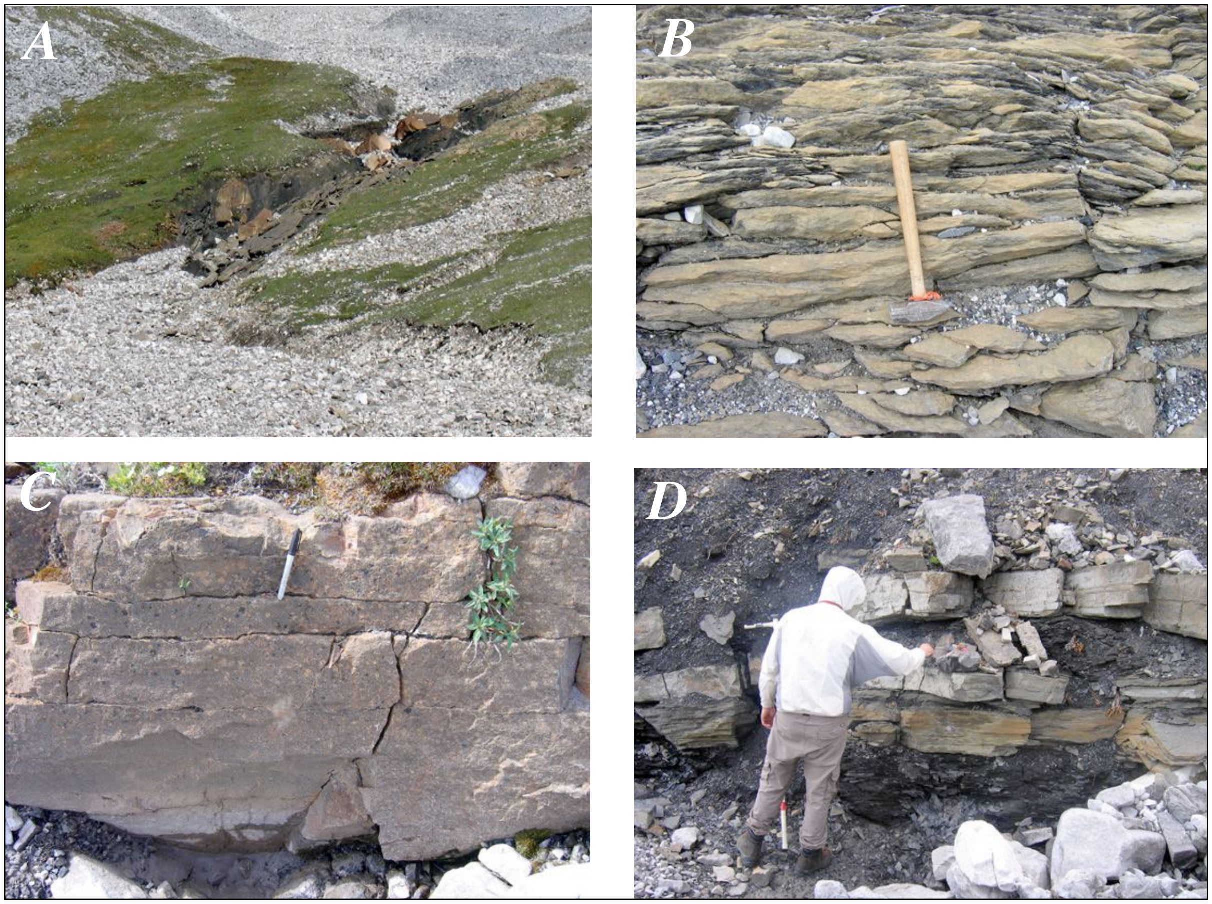

Figure 4. Kayak Shale at May Creek (loc. 1, fig. 1). A, Overview, looking downhill to northeast. B, Thin-bedded, yellow-orange-weathering, argillaceous limestone ~1 m above base of measured section (abs). C, Thin- to thick-bedded, orange-weathering pelmatozoan grainstone with bryozoans and brachiopods, 17 m abs. D, Interbedded dark-gray calcareous shale and yellow- to orange-weathering wacke-packstone, 19–21 m abs.

Figure 5 (right). Lower Lisburne Group at May Creek (loc. 1, fig. 1); A–C, lower dolomitic unit; D, dark-weathering unit; E, F, upper dolomitic unit. A, Light-gray-weathering pelmatozoan supportstone overlies thinner bedded, cherty, muddy limestone, ~155–158 m above base of measured section (abs). B, Dolomitized pelmatozoan grainstone with trough cross-bedding, 190 m abs. C, Skeletal wacke-packstone with abundant black chert nodules, 149 m abs. D, Silicified rugose corals in dolomitic wacke-packestone with brachiopods and pelmatozoan debris, 224 m abs. E, Cross-bedded, dolomitic pelmatozoan grainstone, 300 m abs. F, White-weathering porous dolostone with relict pelmatozoan fragments, minor glauconite, 5–7 percent vuggy porosity, and traces of dead oil, 248 m abs.

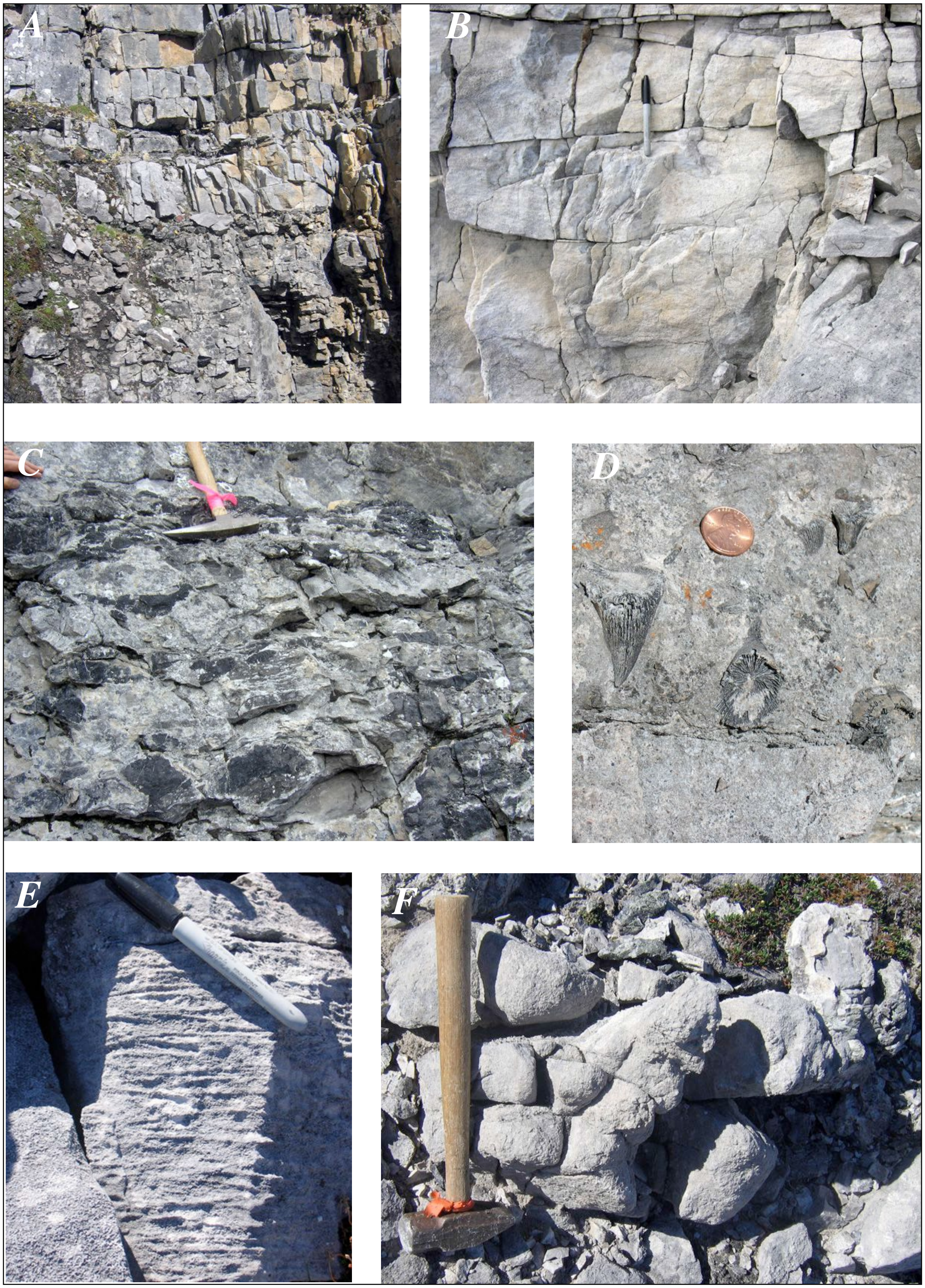
A
B
C
D
E
F

Table 1. Foraminiferal data from the lower part of the Lisburne Group, east May Creek, northern Alaska (loc. 1, fig. 1). Foraminifers identified by P. Brenckle, 2008. f, foraminifer; a, algae; i, incertae sedis.

FIELD NO.	QUADRANGLE LATITUDE/ LONGITUDE	CALCAREOUS FORAMINIFERS AND RELATED MICROFOSSILS	AGE	REMARKS
MCA 75.5	Chandler Lake B-1 ~68°22.127' 150°10.778'	?*Tournayella/Eotournayella* sp. (f) cf. *Eoforschia moelleri* (f) *Asphaltinoides macadami* (i) *Proninella* sp. (a) ?kamaenids (a) *Aphralysia matthewsi* (a) ?*Tournayella vespaeformis* (f) *Stacheoides tenuis* (a) ?*Aoujgalia* sp. (a)	late Early Mississippian (early Osagean; late Tournaisian)	Sample from May Creek measured section, ~50 m above base of Lisburne Group, near top of basal unit. Sample is pale yellow-brown-weathering, medium-gray supportstone in beds 10 to 40 cm thick; thin section is an irregular (partly bioturbated?) mixture of packstone and grainstone with pelmatozoan, bryozoan, and brachiopod fragments, as well as ostracodes, foraminifers, algae, and gastropods.
MCA 241.4	Chandler Lake B-1 ~68°22.065' 150°11.037'	?*Eoforschia moelleri* (f) *Eogloboendothyra/Globoendothyra* sp. (f) cf. *Eoendothyranopsis* sp. (f) *Neoparadainella* sp. (f)	?mid-Mississippian (?late Osagean–early Meramecian; early Visean)	Sample from May Creek measured section, ~216 m above base of Lisburne Group, near top of dark-weathering unit. Sample is thin-bedded, medium-gray-weathering, dark-gray cherty limestone with abundant solitary and colonial corals; thin section is dolomitic, partly silicified wackestone (to packstone) with abundant foraminifers as well as coral, pelmatozoan, bryozoan, and brachiopod fragments, ostracodes, siliceous sponge spicules, and minor peloids.
08AD8A	Chandler Lake B-1 ~68°21.935' 150°10.624'	*Earlandia moderata* group (f) *Earlandia elegans* group (f) ?*Eblanaia* sp. (f) umbellid (a) *Tournayella/Eotournayella* sp. (f) cf. *Eoforschia moelleri* (f) *Earlandis minima* group (f) *Granuliferelloides gloriosa* (f) *Earlandia clavatula* group (f) *Eogloboendothyra/Globoendothyra* sp. (f) *Asphaltinoides macadami* (i)	late Early Mississippian (early Osagean; late Tournaisian)	Basal unit of Lisburne Group exposed ~0.5 km southeast of May Creek measured section. Sample is gray- to grayish-orange-weathering, medium- to medium-dark-gray limestone; thin section is skeletal supportstone with pelmatozoan, bryozoan, and brachiopod fragments, as well as ostracodes and foraminifers.

~280 m of the Lisburne are Osagean; ~ 40 km to the east near Atigun Gorge, the basal ~350 m of the Lisburne are Osagean (fig. 1; Dumoulin and others, 1997). Foraminifers suggest that at least the basal 300 m of the Lisburne are Osagean ~10 km to the east at Itkillik Lake (fig. 1; Armstrong and Mamet, 1977, based on correlation of Mamet foraminifer zones and North American stages by Poole and Sandberg, 1991, and Watts and others, 1994).

Peregrine Creek

A quick examination of the lower Lisburne Group in an area ~7.5 km west of our May Creek section (loc. 2, fig. 1) found a stratigraphic succession very similar to that at May Creek. The Kayak Shale is not exposed here, and the base of the Lisburne is a fault (the base of thrust sheet 4 mapped by Kelley, 1988). Yellow-orange-weathering pelmatozoan grainstone is overlain by light-gray-weathering, light-gray to brown-gray, medium to coarse crystalline dolostone with local cross-beds. Some samples have vuggy porosity that is partly filled with dead oil.

The lower Lisburne Group was also examined ~10.5 km west of our May Creek section (loc. 3, fig. 1) in thrust sheet 5 (Kelley, 1988). At this locality, a small exposure of black fissile shale, locally slightly calcareous and containing diverse concretions as much as 8 cm in diameter, likely represents the Kayak Shale. Some concretions are septarian, with white calcite veins cutting black siliceous shale; others are reddish brown and may be sideritic. Rubble of partly dolomitized limestone overlies this shale and is in turn overlain by white-weathering dolostone with minor porosity and traces of dead oil.

LISBURNE GROUP (UPPER PART) AND SIKSIKPUK FORMATION

We examined the upper part of the Lisburne Group, as well as overlying Permian strata (Siksikpuk Formation), at several localities between Peregrine and Cobblestone creeks and measured a partial section of the upper Lisburne along the western fork of Peregrine Creek (locs. 4–7, fig. 1). All of these outcrops are in the northernmost of the Lisburne-bearing thrust sheets mapped by Kelley (1988). We also sampled the uppermost Lisburne in thrust sheet 4 west of Peregrine Creek (loc. 3, fig. 1).

West Peregrine Creek

The Lisburne Group is well exposed through a small canyon on the west fork of Peregrine Creek (loc. 4, fig. 1; figs. 6A, B). We examined most of the uppermost 65–75 m of this succession (an interval ~20 m thick in the lower half of these beds was inaccessible due to high water levels). Kelley (1988) and Mull and others (2009) mapped a depositional contact between the Lisburne and the overlying Siksikpuk Formation in this area, but the contact itself is covered; an interval of tundra separates the highest exposures of Lisburne from the lowest exposures of Siksikpuk.

The upper Lisburne Group consists of ~1- to 2-m-thick alternations of grainier and muddier strata. Grain-supported rocks are mostly medium gray, thin to medium bedded, and weather to medium- to light-brownish-gray. In thin section, samples are irregular (partly bioturbated?) mixtures of pelmatozoan grainstone and bryozoan packstone; other bioclasts are mostly disarticulated brachiopod fragments (locally abundant) and rare ostracodes. Several samples contain a few phosphatic bioclasts and patches, and one has minor glauconite. Muddier intervals are dark-gray, thin- and locally nodular-bedded lime mudstones to wacke-packstones that contain the same fauna as the grainier strata plus locally notable siliceous sponge spicules. Black, light-gray, and white chert, as large ovoids, bands, and irregular nodules, forms 10–50 (generally ≤30) percent of all mud-supported and about half of the grain-supported intervals (fig. 6C). Minor amounts of dolomite replace lime mud in both mud-supported and grain-supported rocks. The Lisburne section on west Peregrine Creek has not been dated, but regional correlations (described below) suggest an age of late Late Mississippian–Middle Pennsylvanian.

Strata mapped by Kelley (1988) and Mull and others (2009) as Siksikpuk Formation in the Peregrine Creek area are medium-dark-gray to dark-gray shale and silty shale with local barite nodules and concentrically laminated fine-grained carbonate concretions (fig. 6D). These rocks resemble the upper part of the Permian succession described by Siok (1985) at Cobblestone Creek, ~5 km to the east. Orange-weathering interbedded dolostone and claystone, like those reported by Siok (1985) to make up the lower part of the Permian section at Cobblestone Creek, were not observed at Peregrine Creek.

Other Localities

Additional lithologic and age data for the upper part of the Lisburne Group come from several localities east and south of the west Peregrine Creek section. Siok (1985) describes the uppermost beds of the Lisburne Group 1 km east of Cobblestone Creek (loc. 5, fig. 1) as gray, medium to coarsely crystalline limestone; these strata are overlain along a wavy contact by orange-weathering dolostone and interbedded claystone of the Siksikpuk(?) Formation that contain Wolfcampian (Early Permian) brachiopods. Conodonts from the uppermost 1 m of the

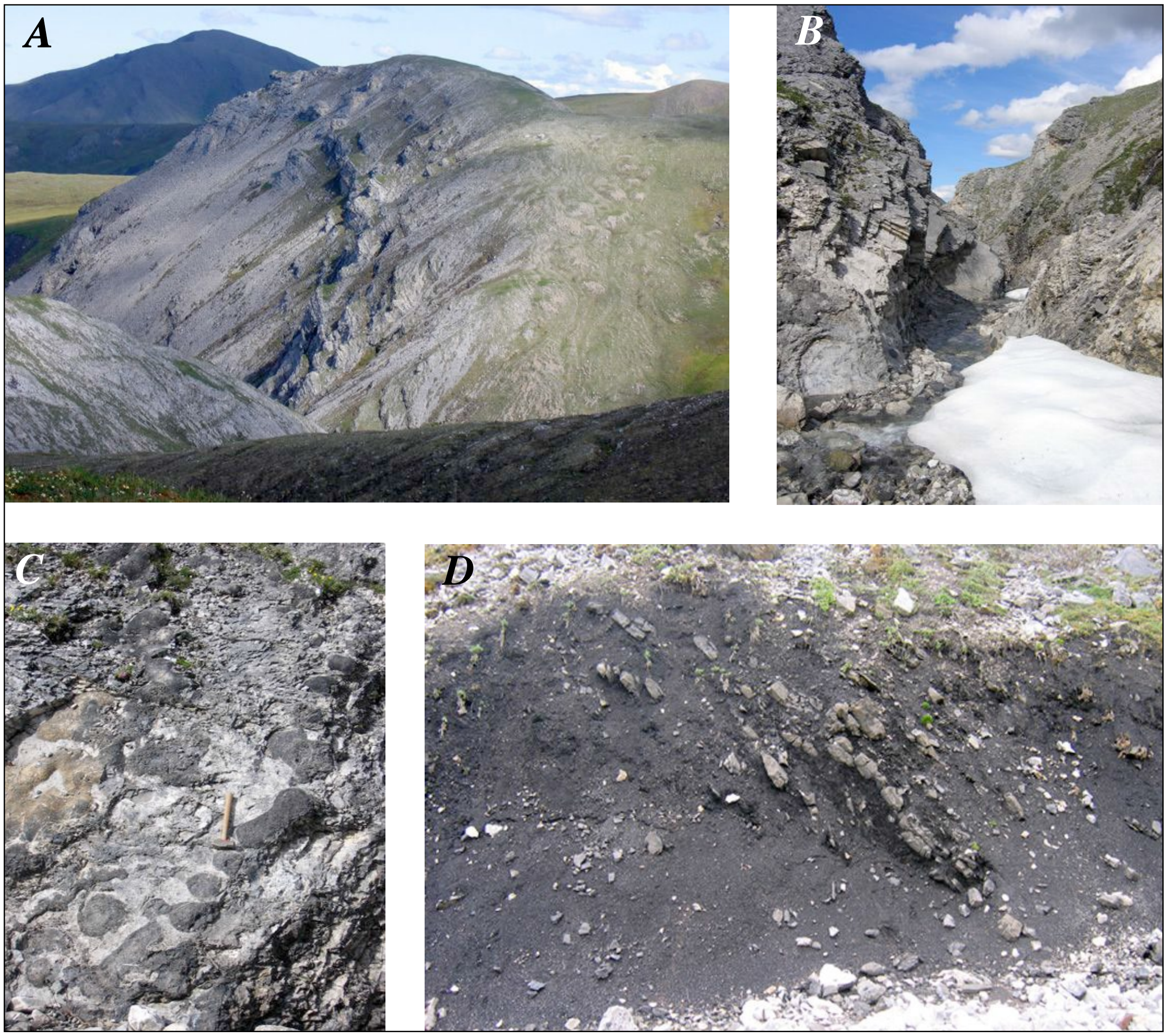

Figure 6. Upper Lisburne Group (A–C) and overlying Permian strata (D) at West Peregrine Creek (loc. 4, fig. 1). A, Overview, looking northeast. B, Closer view, looking north. C, Large chert nodules in lime mudstone to wackestone. D, Dark-gray shale with abundant carbonate concretions.

Lisburne at this locality are of late early Morrowan (Early Pennsylvanian) age and have color alteration indices (CAIs) of 3.5–4 (Siok, 1985).

We measured 32 m of the upper Lisburne Group on the east fork of Peregrine Creek, ~4.5 km west of the section sampled by Siok (1985), and also examined several meters of section and associated rubble on a hillside <1 km to the east (locs. 6, 7, fig. 1). The contact with the Siksikpuk Formation is not exposed at either site, but the Siksikpuk crops out just downstream to the north (Kelley, 1988); the rocks we examined represent the highest exposures of the Lisburne in this area. The strata at east Peregrine Creek are in part like those at west Peregrine, with meter-thick alternations of light- to medium-gray supportstones and medium- to dark-gray muddier rocks. Bioclasts in both facies are mostly pelmatozoan and bryozoan fragments, with lesser ostracodes and brachiopods. Some lime mud is partly replaced by finely crystalline dolomite. The east Peregrine Creek rocks contain little chert, however, and include some fossils and lithofacies not seen to the west. Foraminifers, algae, and solitary and colonial rugose corals occur locally, chiefly in supportstones, and the uppermost 6 m of the measured section consist of black calcareous shale with subordinate thin interbeds of bryozoan–pelmatozoan supportstone.

The Lisburne Group section that we measured at east Peregrine Creek is at least in part older than the uppermost Lisburne dated by Siok (1985). Bryozoan–pelmatozoan supportstone 14 m below the top of our section produced conodonts that are no younger than middle Chesterian (late Late Mississippian); pelmatozoan–bryozoan grainstone 15 m lower yielded conodonts no younger than early Chesterian (table 2). Thus, strata of Pennsylvanian age have not been found at this locality, but the uppermost part of the section has not been dated and could be Pennsylvanian. It is also possible that the east Peregrine section was structurally disrupted and the uppermost beds were tectonically removed. CAIs of the east Peregrine conodont faunas are 2–3 (table 2).

We briefly examined the highest exposures of the Lisburne Group in thrust sheet 4, ~3 km south of our west Peregrine Creek section (loc. 3, fig. 1); the top of the Lisburne in this area is a fault. The uppermost Lisburne here consists of medium-light-gray-weathering, medium-gray, pelmatozoan–bryozoan grainstone in 25- to 40-cm-thick beds with wavy internal partings and subordinate, bored brachiopod fragments. Conodonts indicate an Early–Middle Pennsylvanian age for these rocks (A.G. Harris, written commun., 2006).

DEPOSITIONAL SETTINGS

Lithofacies and faunal data suggest that the lower part of the Lisburne Group in the Cobblestone Creek area accumulated chiefly in midramp to inner-ramp settings, whereas the upper Lisburne Group was likely deposited in somewhat deeper, midramp to outer-ramp environments. Thick intervals (>5 m) of cross-bedded dolomitic pelmatozoan grainstone in the lower Lisburne resemble those seen to the west in correlative strata at Shainin Lake (fig. 1; Bowsher and Dutro, 1957; Dumoulin and others, 1997) and probably formed as sand-wave and shoal deposits of the inner midramp to inner ramp. These rocks are medium-bedded to massive and contain little or no mud. Muddier strata intercalated with the grainstones have thinner, locally nodular beds, are commonly spiculitic, and accumulated in quieter (and in part deeper?) water settings of the midramp.

Supportstone intervals in the upper part of the Lisburne Group, in contrast to those in the lower Lisburne, are thinner (1–2 m), thinner bedded (≤40 cm), and contain more mud; we interpret these strata as storm deposits of the midramp (to outer ramp?). Interbeds of black shale at localities 6 and 7 (fig. 1) also imply a relatively deep-water environment, as do intervals of thin- to nodular-bedded, spiculitic limestone at locality 4 (fig. 1).

REGIONAL COMPARISONS

The lower part of the Lisburne Group in the Cobblestone Creek area is similar in many respects to correlative rocks to the west at Shainin Lake and Skimo Creek, to the east at Itkillik Lake, and to the southwest along the Nanushuk River (fig. 1). At Shainin Lake, intervals of cross-bedded, commonly dolomitized pelmatozoan grainstone alternate with thinner bedded, cherty to muddy limestone throughout the lower two-thirds of the Lisburne section (Dumoulin and others, 1997). Interval and bedding thicknesses, sedimentary structures, and microfacies of these grainstones match well with those of the May Creek dolomitic supportstones. The Shainin Lake dolostones have porosities as high as 11 percent (Krynine and others, 1950) and contain local dead oil, and their protoliths likely formed in a belt of skeletal sand shoals (Dumoulin and others, 1997). Similar porous, dead oil-bearing dolostones are found in coeval strata at Skimo Creek, but shoal facies in this area are less extensively developed (Dumoulin and others, 2008). Shallow-water shoal facies that include porous dolostones also occur in the lower part of the Lisburne at Itkillik Lake (Krynine and others, 1950; Armstrong and Mamet, 1977; Dumoulin and others, 1997) and near the Nanushuk River (White and Whalen, 2006; White, 2007). Along the Nanushuk, the lower Lisburne contains >100 m of thick-bedded to massive dolostone with as much as 15 percent intercrystalline and vuggy porosity, local dead oil, and interlayers of thin-bedded, cherty mudstone (White, 2007).

The upper part of the Lisburne Group, as well as the overlying Permian section, is distinctive in the Cobblestone Creek area. At Shainin and Itkillik lakes, the highest Lisburne is Chesterian and the contact with the Sikisikpuk Formation is not preserved; the upper contacts in these areas are a Holocene erosion surface and a thrust fault, respectively (Armstrong and Mamet, 1977). The contact between the Lisburne and the Siksikpuk is well exposed farther west at Skimo Creek, however, and the uppermost Lisburne in this area is early Morrowan (Dumoulin and others, 2008) and thus correlative with the uppermost Lisburne at Cobblestone Creek locality 5 (and more broadly, locality 3, fig. 1). But the facies of the upper Lisburne and lower Siksikpuk at Skimo Creek differ markedly from those of correlative rocks in the Cobblestone Creek area. The upper 40 m of the Lisburne Group at Skimo Creek are mainly dark shale, lime mudstone, and spiculite, with an interval of glauconitic grainstone. Lime mudstone and spiculite occur in the uppermost Lisburne at localities 4, 6, and 7 (fig. 1) but are intercalated with abundant skeletal supportstones not found at Skimo Creek.

The overlying Permian section also differs between the two areas. Skimo Creek is the type section for the lower part of the Siksikpuk Formation (Patton, 1957), which consists of bright-yellow-weathering claystone and siltstone with a thin interval of argillaceous limestone that contains Wolfcampian (Early Permian) brachiopods (Siok, 1985) and conodonts of likely Early Permian age (Dumoulin and others, 2008). These beds are overlain by red, green,

Table 2. Conodont data from the upper part of the Lisburne Group, east Peregrine Creek, northern Alaska (loc. 6, fig. 1). Conodonts identified by A. Krumhardt and A.G. Harris, 2007; CAI rechecked by J.E. Repetski, 2008. CAI, conodont color alteration index.

FIELD NO.	QUADRANGLE LATITUDE/ LONGITUDE	CONODONTS	AGE AND BIOFACIES	CAI	REMARKS
COB-14	Chandler Lake B-1 68°23.253' 150°23.71'	23 Pa elements *Hindeodus* aff. *Hi. crassidentatus* (Branson and Mehl) *Hindeodus* spp indet. 34 Pa, 6 M, 8 Sc elements *Kladognathus* spp. indet. 60 M, 16 Sa, 51 Sb/Sc elements 2 Pb? elements *Idioprionidus* spp. indet. Unassigned elements: 2 Pa, 28 Pb (2 morphotypes) 125 indet. bar, blade, and platform frags	Mississippian (late Osagean to middle Chesterian). Kladognathid/hindeodid biofacies; indicates normal marine setting, above wave base.	2–3	Section here is overturned; sample taken 14 m below top of Lisburne Group. Siksikpuk Formation is exposed just downstream from this locality. Sample is medium light-gray, dm-bedded, argillaceous limestone that weathers brownish-gray. Thin section is bryozoan–pelmatozoan supportstone with ostracodes, brachiopods, algae?, and scattered dolomite rhombs. 10 kg of rock processed. Heavy mineral concentrate includes common indeterminate phosphatized bioclasts and phosphatic clasts.
COB-29		6 Pa elements *Bispathodus utahensis* Sandberg and Gutschick 3 Pa elements *Hindeodus* aff. *Hi. crassidentatus* (Branson and Mehl) *Kladognathus* spp. indet. 1 P, 1 Pb, 3 Sb/Sc elements Unassigned elements: 8 Pa 17 indet. bar, blade, and platform frags	Mississippian (latest Kinderhookian–early Chesterian). Hindeodid/bispathodid biofacies; relatively shallow water depositional environment.	2–3	Sample taken 29 m below top of Lisburne Group. Sample is medium-brownish-gray limestone that weathers medium gray, forms 20- to 30-cm-thick beds, and contains brachiopods and solitary rugose corals. Thin section is pelmatozoan–bryozoan grainstone with ostracodes and foraminifers. 10.5 kg of rock processed. Heavy mineral concentrate includes phosphatic clasts.

and gray shale, siliceous mudstone, and siltstone of Early to Late(?) Permian age (Siok, 1985). Strata overlying the Lisburne Group in the Cobblestone area (loc. 5, fig. 1), however, are yellow- to orange-weathering dolostone and lesser claystone ("Siksikpuk Formation?" of Siok, 1985) that contain a Wolfcampian brachiopod fauna more like coeval assemblages in the eastern Brooks Range than at the Siksikpuk type section. The upper part of the Cobblestone section described by Siok (1985) is exposed ~1.5 km northwest of locality 5 (fig. 1) and consists mostly of dark-gray shale with concentrically laminated nodules of dolostone and siderite. Similar concretion-bearing dark shales occur above the Lisburne at locality 4 (fig. 1). These rocks are unlike the variegated cherty shale and mudstone characteristic of the Siksikpuk Formation and were called possible Echooka Formation by Siok (1985). The overall Permian succession at Cobblestone Creek is similar to that exposed to the east along the Atigun River (a few kilometers north of loc. AR, fig. 1) and appears to represent a facies transition between the Siksikpuk and Echooka Formations (Adams and Siok, 1989).

East to west differences in stratigraphic successions of the Lisburne Group (and perhaps overlying Permian strata as well) likely reflect tectonic factors. The Morrowan drowning of the Lisburne carbonate platform in the Skimo Creek area occurs during a time of progradation of the Lisburne in the eastern Brooks Range, and may be due to downdropping of parts of the central Brooks Range along reactivated extensional structures (Whalen and others, 2005, 2006; Dumoulin and others, 2008; see also Kelley and Brosgé, 1995). Lateral changes in late Paleozoic facies of northern Alaska may also be due to variation in nature and amount of sediment influx along the continental margin at this time.

Conodont CAIs in the Lisburne Group at Cobblestone Creek are relatively high (3.5–4.0; Siok, 1985) but are lower at east Peregrine Creek (2–3; table 2). The higher values indicate minimum temperatures of 150–190°C (Epstein and others, 1977; Watts and others, 1994), above the limit of oil preservation (Bird and others, 1999); the lower values denote minimum temperatures of 60–120° and fall within the oil window. The Peregrine Creek values are comparable to Lisburne CAIs reported from the west (for example, 1–2.5 at Skimo Creek; Dumoulin and others, 2008) and to the east (2–3 at Atigun River, Dumoulin and others, 1997). In the Skimo Creek area, CAI values differ somewhat between thrust sheets (Dumoulin and others, 2008). The Cobblestone Creek CAI data above all come from the northernmost thrust sheet; samples from other thrust sheets in this area would be very useful.

CONCLUSIONS AND FUTURE WORK

Our reconnaissance study of the Lisburne Group in the Cobblestone Creek area found strata with hydrocarbon reservoir potential and intriguing similarities and differences to nearby coeval sections. Locally porous dolomitic supportstones occur in the lower part of the Lisburne in the three southernmost thrust sheets and correlate well with similar rocks known from Skimo Creek to Itkillik Lake. The upper part of the Lisburne, in contrast, as well as overlying Permian strata, differs in lithofacies and biofacies from coeval rocks at Skimo Creek. Promising avenues for future work in the Cobblestone Creek area include comprehensive comparison of Lisburne lithofacies and conodont CAI values between thrust sheets, and documentation of lateral and vertical changes in porosity and dead oil content within the dolomitic supportstone intervals. One particularly important unanswered question is whether porous dolostone intervals occur in the lower Lisburne of the northernmost two thrust sheets in the Cobblestone Creek area, and if so, how these intervals compare with those seen to the south. Finding evidence for shifts in the degree and extent of Lisburne porosity between thrust sheets would have crucial implications for predicting Lisburne reservoir quality in the subsurface to the north.

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