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U.S. Geological Survey

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Preliminary Report 37

PRELIMINARY REPORT ON THE STRATIGRAPHY AND STRUCTURE OF

THE KILIGWA RIVER AREA, ALASKA

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By

I. L. Tailleur, B. H. Kent,

and H. N. Reiser

November 1951

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ILLUSTRATIONS

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OF THE KILIGWA RIVER AREA, ALASKA

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INTRODUCTION

The 1951 field program for Navy Oil Unit party 3 was undertaken with a twofold purpose: (1) to investigate the apparent anticlinorium in the Torok formation (Lower Cretaceous) where exposed along the lower reaches of the Ipnavik, Kiligwa, and Nuka Rivers; and (2) to extend the mapping of the west-central Southern Foothills section initiated in 1950 and determine the relationships of the geology of the foothills to that of the Brooks Range to the south.

The party was made up of seven men: three geologists, two field assistants, a cook, and a weasel mechanic. Tailleur and an assistant were landed at the Range front on the Ipnavik River by ski plane on May 27, 1951, to begin a boat traverse of the river. Kent and Reiser, with the remainder of the party, were flown to Lake Noluk on May 28 to begin the weasel traverse of exposures of the Torok formation along the lower Nuka and Kiligwa Rivers. Most of June was spent in completing these surveys; the two groups did not join until June 22 at Liberator Lake.

Exceptionally poor weather prevented the party from accomplishing its scheduled work along the east fork of the Kiligwa River. Consequently, the traverses of the De Long Mountains were not begun until late August. A heavy snowfall on September 5 forced abandonment of field operations, leaving unmapped the area of the headwaters of the west fork of the Kiligwa River and the east fork of the Nuka River. The weasels were driven to the Driftwood camp and cached.

Weather caused a 40 percent loss of working time during the season, 25 days of which were in the period between July 10 and September 1. Poor weather also delayed departure of some of the party from Driftwood and Umiat until October 1. One cache containing a month's collection of rock samples had to be left in the field, possibly until freeze-up.

Vertical photograph uncontrolled mosaics assembled by the U. S. Geological Survey in 1951 were used as a base for field mapping; trimetrogon photographs and trimetrogon planimetric maps were used for areas where vertical photo coverage was lacking. Relative altitudes were established by altimeter.

The greater part of the area covered by this report is adjacent to the Kiligwa River in the west-central Southern Foothills section, Arctic

Foothills province. This area is shown on plate 1; the remaining areas studied, but not shown on the areal map, include (1) the eastern end of the De Long Mountains south of the foothills, and (2) a narrow band along the Ipnavik River. As field data have not been received, maps of these smaller areas have not been completed. Results of the boat traverses on the Ipnavik and Kiligwa Rivers are presented as a separate part of this report.

Previous work in the Kiligwa River area was limited to brief reconnaissance by Tailleur and Kent in 1950.1/ The central part of the Ipnavik River was covered in the same survey. Stefansson traversed the central and lower Ipnavik in 1947.2/

Topography.--The area of the Kiligwa River can be readily divided into three topographic or geomorphic units. The northernmost unit is a flat plain of very low relief along the lower reaches of the Kiligwa and Nuka Rivers, where underlying fine clastics of the Torok formation are relatively nonresistant and have permitted near planation.

The intermediate belt, produced by differential erosion of folded strata of Mississippian to Cretaceous age, is limited on the north by the Liberator Ridge and on the south by the De Long Mountains. Maximum relief is about 1,000 feet. Ridges of the more resistant beds and intervening areas of relatively low relief are cut by major north-flowing rivers that are incising their broad alluvial floodplains.

The southern topographic belt includes the De Long Mountains and is an area of complex, broadly folded Mississippian rocks and associated sills. They are eroded into rampartlike ridges that rise 1,500 to 2,500 feet above the surrounding terrain. A southeast-plunging synclinorium terminates the mountains.

STRATIGRAPHY

Because none of the faunal collections have been studied, the following discussion is subject to revision. Rocks ranging from Devonian to late Lower Cretaceous age were identified in the Kiligwa River area. Lithologic units that are correlative with or comparable to previously described sections are Devonian rocks; the Kayak3/ formation (formerly Noatak), and the Lisburne limestone (Mississippian); the Siksikpuk group (Pennsylvanian (?)-Permian); the Shublik formation (Triassic); and the Okpikruak and Torok formations (Lower Cretaceous).

Devonian rocks

Along the east fork of the Kiligwa River 6 miles east of camp 8, a 700-foot section of Upper Devonian strata was examined and detailed

1/ Tailleur, I. L., and Kent, B. H., Stratigraphy and structure of the Southern Foothills section between the Etivluk and Kiligwa Rivers, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 43, June 1951.

2/ Stefansson, Karl, Stratigraphy and structure of the area of the Ipnavik River, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. No. 14, 1948.

3/ Patton, W. W., Jr., Brosge, W. P., and Mangus, M. D., Preliminary report on the geology of the Okokmilaga and John Rivers area, Alaska: U. S. Geol. Survey Navy Oil Unit Prelim. Rept. 38, 1951.

measurements made. The section consists chiefly of fine-grained limestone with some silicified beds. As an abundant faunal assemblage was collected in 1950, no new fossils were collected. The section is part of a thrust sheet, itself being overthrust by a series of igneous rocks and Mississippian strata which cut out the Devonian to both the east and west. Devonian rocks also are exposed 2 miles west of camp 8 in a series of east-trending small outcrops. These crops appear to lie along the strike and probably are continuous with the same thrust sheet of Devonian limestone. Other outcrops of probable Devonian age were measured on the south side of the Brooks Range in the Ahbalah River drainage area. These are faulted sections which require more complete fossil identification before they can be correlated with other sections.

Mississippian rocks

Kayak formation

The largest section of Kayak formation crops out along the Ipnavik River 157° 20' W., 68° 20' N. Because of the large amount of rubble and covered section, an accurate measurement could not be made; the section consists of a maximum of 1,500 feet and a minimum of 750 feet of predominantly dark-gray slate with some interbedded quartzite. The section is conformably overlain by a dark, fine-grained limestone of the Wachsmuth member.

At the headwaters of the Kuna River 750 to 850 feet of Kayak formation consists of dark silt and clay shale with scattered beds of limy quartzitic sand. Also in the area incomplete sections 100 to 150 feet thick consist of argillite, shale, and silt with dark-gray, fine-grained, red-weathering limestone. At the top of the 750- to 850-foot section are several beds of red-brown-weathering quartzite and limy, quartzose sandstone that possibly are equivalent to the lower quartzose Lisburne limestone measured by party 1 in 1949.4/

Lisburne limestone

In the area traversed by party 3 in 1951, outcrops of rocks of Lisburne age are few. In the Kiligwa River drainage in the Southern Foothills section, Lisburne limestone at lat. 68° 42' N. occurs entirely in fault blocks and ridges. Alinement of these fault blocks indicates a series of reverse and thrust faults parallel to the major east-west structural trend. Diabase intrusives are closely associated and have bleached and altered the limestone and chert. The more persistent ridges are largely bleached limestone and chert rubble overlying and upheld by diabase cores. Farther south in the area of the De Long Mountains the Lisburne limestone consists almost completely of dark, fine-grained, thin-bedded limestone and interbedded black chert of the Kiruktagiak member. Black chert constitutes 70 to 90 percent of the rock. The longer and more persistent ridges are intruded and capped by numerous diabase sills. Ridges of Kiruktagiak chert are faulted over Mesozoic rocks.

4/ Sable, E. G., and Mangus, M. D., Stratigraphy and structure of the upper Utukok-Kokolik Rivers area, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 45, 1951.

Wachsmuth member.--At the headwaters of the Kiligwa 158° 60' W., 68° 30' N., approximately 100 feet of crinoidal, fine- to coarse-grained, medium-gray limestone of the Wachsmuth member crops out as a klippe. Owing to the crushed and contorted condition of the limestone, an accurate measure was not possible.

Along the Ipnavik River traverse and in the headwaters area of the east fork of the Kuna River the Wachsmuth member conformably overlies the Kayak formation. Sections in these areas are 100 to 150 feet thick and are dense, fine-grained crinoidal limestone, thin-bedded to shaly, with interbedded chert and shale. The Wachsmuth is thinner, more shaly and cherty than that at Kanayut Lake.

Alapah-Kiruktagiak members.--The Alapah and Kiruktagiak members constitute over 95 percent of the Lisburne seen. Three distinct lithologic phases were observed: an uppermost zone of sandy quartzitic limestone, conglomeratic, with distinctive green glauconite (?). It overlies both the other distinct phases, which may be partly equivalent in age. The second distinct phase is dark, fine-grained, shaly, cherty limestone of the Kiruktagiak member. The third is olive-gray, fine- to coarse-grained limestone, medium-bedded with minor amounts of chert. Lithologically it is similar to zone 4 of the Alapah member. Outcrops of this unit are restricted roughly to an area between 68° 41' N. and 68° 33' N. and may be equivalent to and grade into the Kiruktagiak to the south. As much as 120 feet of this limestone crops out in steep dipping fault blocks. These fault outcrops probably represent only a part of the subsurface thickness. The larger faults are shown on the map, but most of the fault blocks are too small to be plotted at the 1:96,000 scale.

At the southern border of the Southern Foothills section is approached the outcrops of Lisburne limestone consist of an increasing percent of the Kiruktagiak member. In the De Long Mountains where the Lisburne outcrops are essentially all Kiruktagiak member, the thick-bedded black chert comprises approximately 70 percent of the section. Because of the comparatively gradual southward decrease in the occurrence of Alapah facies, it is believed that the Alapah member grades southward into a thick zone of Kiruktagiak member, possibly representing a more quiet, deepwater depositional basin. A restored section of 1,500 feet (plus or minus 300 feet) of Kiruktagiak member, faulted and intruded by diabase sills, was computed for the De Long Mountains. It consists dominantly of gray-black, 4- to 6-inch beds of chert interbedded with fine-grained, dark-gray, silicified limestone in beds 1 to 2 inches thick.

The limy quartzitic sandstone that marks the top of the Lisburne limestone was exposed in river cuts and in a low zig zag ridge surrounded by tundra. The distance between the most northerly and southerly exposure is approximately 5 miles--indication of the minimum north-south extent of this horizon. The most complete section measured is also the most northerly exposure of this horizon. It is a 90-foot-thick fault slice, wedged between probable Jurassic shale. It consists of a basal 25-foot conglomeratic limy silt with pebbles of silt stone; this grades up into a coarse-grained, sandy limestone containing abundant quartz and chert grains with minor interbeds of fine-grained limy silt shale. The over-all greenish color of the section is due to the presence of abundant green glauconite (?). Field examination of the fossils obtained indicates high zone 8 or 9 of the Alapah member. Outcrops farther south in the foothills lack the conglomeratic beds and appear better sorted. It is believed that these are equivalent to and grade into the coarse quartzose sandstone facies of Lisburne limestone that were described and mapped by party 5 in 1950. 5/

Permian system

Strata overlying Mississippian limestone and underlying Triassic rocks were mapped as Permian. At the mountains, where most completely exposed, they are composed of 200 feet of clay-silt shale, somewhat siliceous and generally well indurated, that weather to bladelike fragments. On fresh surfaces the shale is dark but weathers deeply to a distinctive dark red. Fifty feet of bedded, dark medium gray glassy chert overlies the shale. Where strongly altered, the chert is bleached and the surfaces are stained a brilliant yellow orange.

No complete section was observed in the northern part of the complex area. Black ferruginous chert, fossiliferous calcareous shale, and some red- and dark-green-weathering chalcedonic chert are believed to be correlative with the beds to the south.

Triassic system

Within the foothills belt an upper unit of the Shublik formation is present as typical chert, silicified limestone and siltstone, and sublithographic limestone. This upper unit is exposed over much of the area but seldom in complete thickness because of pre-Jurassic erosion. The maximum measured thickness is 180 feet. Underlying it is a seldom exposed section of thinly bedded, dark clay shale, measured as 275 to 300 feet thick.

In the south near the mountains, less limestone is present and the section has been more extensively silicified. Argillaceous beds are also more abundant. The lower shale unit was not recognized; if present, it is very thin.

On the south side of the mountains even less limestone was observed; the section appears to be dominantly fine clastics. One exposure of dark shale contains silt beds with plant impressions and phosphatic nodules.

Jurassic system

A pattern of rapidly changing facies together with small and infrequent rock exposures make it impossible to establish the true stratigraphic relation of the various Jurassic rocks seen. In the Southern Foothills

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5/ Tailleur, I. L., and Kent, B. H., Stratigraphy and structure of the Southern Foothills section between the Etivluk and Kiligwa Rivers, Alaska: U. S. Geol. Survey Navy Oil Unit Rept. 43, 1950.

section the base of the Jurassic consists of a thin sequence of clay shale containing coquina of Aucella bronni. This clay shale is equivalent in time to an interbedded sharpstone conglomerate and fine-grained graywacke that overlies the Triassic elsewhere. A fine-grained, greenish-hued sandstone containing many "cannonball" concretions is approximately 100 feet thick. A series of silt shale and dark-gray silicified siltstone with ferruginous black chert and paper shale lies below the "cannonball" sandstones; if these strata are not equivalent to the basal section, they increase the total thickness of Jurassic in this area.

A section of at least 200 feet of brown clay, silt shale, and dark-brown, fine-grained sandstone is thought to represent another facies of the Jurassic, but pending further study no correlation is made.

South in the De Long Mountains, a 600-foot incomplete section of Jurassic rocks consists primarily of a conglomerate with pebbles and cobbles of granodiorite, diabase, and siltstone. The section grades upward into an interbedded sandstone and siltstone. It is believed that the red and green cherts 400 feet to 500 feet thick that crop out in the northern part of the De Long Mountains overlie and possibly are equivalent to the upper part of this conglomerate sequence.

Possible Jurassic (?)

Several hundred feet of a previously undescribed lithologic sequence occur on the upper east fork of the Kuna River. The upper part is exposed only as float on a cut bank and appears to be composed of shale and very fine grained sandstone and siltstone that is dense, medium to light gray, with occasional light-green cast, moderately well sorted, and locally quartzose. One 2- to 3-foot bed of quartzitic sandstone near the middle yielded coarse-ribbed fossil fragments not yet identified. Fewer coarser beds are present in the lower half. Two zones of chert, 20 to 30 feet thick, occur near the base of the shale; the even bedding and medium-gray color, with greenish cast on bedding surfaces suggests comparison to other Jurassic chert. A resistant series of bedded, siliceous, slightly calcareous shale underlies the chert. Quartzose sandstone beds, present in minor proportions at the bottom, become more massive and predominant toward the top. The flaggy bedding and lamination, together with moderately high induration, make the series a distinctive unit. This is the only known exposure and cannot be correlated to exposures of known age. Pending study of the fossil collection, the beds are included in the Jurassic.

It is evident that the Jurassic Kingak formation[6/] in the Kiligwa River area is extremely varied in composition. Facies changes are recognized. Deposition was marked by at least one, if not numerous, locally significant breaks. The base of the Jurassic section is marked by a basal unconformity.

6/ Patton, W. W., Jr., and Keller, A. S., Stratigraphy and structure of the upper Siksikpuk-Nanushuk Rivers area, Alaska: U. S. Geol. Survey Navy Oil Rept. 42, 1950.

Cretaceous system

Only Lower Cretaceous strata are present in the area. The Okpikruak formation (Neocomian stage) is widespread in complex, relatively large folds along the middle of the complex belt. The Torok formation (Albian stage) is almost the only unit cropping out along the northern margin of the complex foothill belt and in the flats to the north. The Torok formation is described in the section on the Kiligwa River area.

The Okpikruak formation in the Kiligwa River area differs little from exposures farther east. The section in general consists of 60 percent shale interbedded with 40 percent sandstone. A conglomeratic sandstone overlying 5 to 10 feet of basal shale at the contact contains rounded pebbles of chert. The shale is dark and both clayey and silty. The sandstone is generally fine grained, medium gray and green, and calcareous. Some coarser beds are present in which chert grains can be identified. These same beds contain scattered shell fragments. Interbedding of the shale and sandstone is cyclic in parts of the section. Ripple marks are uncommon, but fucoidal markings on the bottoms of the sandstone beds are characteristic. Horizons of abundant Aucella sp. and other scattered fossils are present. In one bed impressions of large valves are oriented concave downward, with the long axis alined S. 60° E., implying currents from that direction. A 1,500-foot shale section was measured on the Kiligwa River.

A sharply folded anticline on the east fork of the Kiligwa River exposes older beds along its axis and Okpikruak formation on the flanks. On the south flank the basal shale and conglomeratic sandstone is in apparent conformable contact with red-weathering chert and shale, questionably Jurassic; on the north flank the same basal beds are in apparent conformable contact with Carboniferous-Permian chert and, in one place, with diabase and chert of the Lisburne limestone. The Jurassic chert is faulted against the Permian section along a zone now filled by diabase. The surface trace of the fault projects under undisturbed Okpikruak strata. Considerable movement must, then, have preceded deposition of the Okpikruak.

IGNEOUS ROCKS

Minor mafic sills have intruded the Triassic and Jurassic strata throughout the complex area. Larger sills have intruded linear ridges of Lisburne that trend across the middle of the complex. Maximum intrusive activity occurred in the present De Long Mountains where several sills 70 to 200 feet thick were emplaced in the Lisburne sequence.

The composition of the sills is constant. Alteration is limited to a 10- to 20-foot zone of baked and bleached interbedded chert and limestone. Some of the sills are laterally persistent for as much as 5 miles, but others are broadly lenticular. Evidently chert zones were more favorable for intrusion, for sills are absent from the shaly sections of the Lisburne.

The presence of the mountains is apparently due in part to the resistant diabase sills that cap the ridges. The enclosing sediments show as traces along the contacts.

STRUCTURE

Folding and faulting in the Kiligwa River area follows much the same pattern as described in the area to the east. Within the complex belt Triassic and Jurassic strata are complexly deformed by isoclinal folds overturned to the north and numerous south-dipping reverse faults. Larger structures are outlined by the general distribution of stratigraphic units, and an undulating, open fold pattern is superimposed.

Along the mountain front a curious concentration of high, north-trending ridges of imbricately faulted Lisburne chert appears to wrap around a partial fenster of Mesozoic rocks. Although broken by numerous faults, the stratigraphic relationships suggest a long erosion interval between the Kiruktagiak member (Lisburne) and Jurassic rocks.

Along the front, imbricate faults are extensive. At one place a 50-foot zone of Permian chert and shale is repeated at least seven times in 1,000 feet of exposure. The displacement on some planes must be great because strata ranging from basal Lisburne limestone through Jurassic are intimately associated in outcrop. In one place a 50-foot sliver of "pre-Lisburne" limestone and shale occurs in a Monotis-bearing (Triassic) sequence.

Areally, the Range is a synclinorium of greenstone sills and Lisburne limestone. Faults and folds modify the outcrop pattern considerably. Sedimentary rocks as young as Jurassic are present along the axial area; discontinuous exposures of Devonian limestone occur along the base of the frontal ridges and trace the change in strike as the structure plunges out.

The relationship of Lisburne limestone to the Devonian is obscure. The Noatak and Kanayut formations are absent. Devonian rocks are faulted over younger beds on both fronts of the mountains.

The flats south of the mountains are underlain by complexly faulted and folded (?) beds ranging from Devonian through Jurassic. No systematic study of field data of that area has been made.

SUMMARY

Rocks of Devonian, Mississippian, Jurassic, and Cretaceous age are exposed in the area studied. Because of small outcrops and complex structure accurate thickness measurements could not be obtained. Devonian rocks are represented by a fault slice 700 feet thick; other units are about 2,300 feet of Mississippian strata, 1,000 feet of upper Carboniferous-Triassic, 2,000± feet of Jurassic, and 4,000± feet of Cretaceous.

Because of its potentialities as an oil reservoir, the Lisburne limestone is of particular interest. In the foothills area the Lisburne is exposed as small fault blocks. It is believed that these fragmentary sections have not removed far geographically from their original location.

Thicker sections outcropping in the foothills and in the Range probably have been moved to their present position by thrust faults. Except for a faulted 100-foot section at the head of the east fork of the Kiligwa, and two small sections in the Kuna and Ipnavik Rivers area, the Wachsmuth member was conspicuously absent in the area studied. A section 1,000 to 1,500 feet thick of the Kiruktagiak member in the De Long Mountains grades northward into a thicker-bedded, more limy, medium grained section of the Alapah member. The top of the Lisburne is a clastic sandy limestone; coarser clastics to the north indicate a northerly source area. This zone would serve as an excellent reservoir rock, though indications are that it is of small extent. No areas favorable for drilling were recognized in the southern portion of the Southern Foothills section.

THE STRATIGRAPHY AND STRUCTURE OF THE

LOWER KILIGWA RIVER

In the physiographic belt between the Liberator Ridge and the Colville River, the presence of large structures has been suggested from previous field work in adjacent areas, photogeologic interpretation, and reconnaissance of the Kiligwa River in 1950.

This physiographic belt is in the northern part of the Southern Foothills section. Structurally, it may be considered intermediate to the broad open structures of the Nanushuk group to the north and the tight isoclinal folds and reverse faults that characterize Paleozoic and older Mesozoic rocks to the south.

Characteristically this belt is one of few exposures which are limited to rubble traces at the crest of the low concordant hills and affords little structural or stratigraphic information in the interstream areas. Exposures are limited to shale and interbedded sandstones of the Torok formation, of such homogeneity that correlation and stratigraphic position of the small isolated outcrops are very difficult to ascertain. The lenticular nature of the beds further complicates the situation.

The lower part of the Kiligwa River, however, is unlike the other major rivers in this region (Kuna, Ipnavik, and Etivluk Rivers to the east, and the Nuka River to the west). It is deeply entrenched and meanders through a narrow river plain. Alluvial deposits are quite thin; bedrock exposure is excellent throughout the course of the lower Kiligwa River, which crosses the strike of the bedrock. Consequently in the hope of gaining more exact information regarding the stratigraphy and structure of the Torok formation, a more detailed traverse of the Lower Kiligwa was made in 1951.

In order to have some stratigraphic control for the Kiligwa River traverse, it was necessary to make the following assumptions:

(1) That the conglomerates that comprise Swayback Mountain are in the upper part of the Torok formation and are the youngest exposures in that region.

(2) That the conglomerate beds in linear alinement and in synclinal structures south of the Liberator ridges plunge east and conformably underlie the top conglomerate bed of Swayback Mountain. They are also of the upper part of the formation.

(3) That the lower shale-siltstone unit is present in the region in general with lithologic characteristics as established in other regions.

The area traversed may be descriptively summarized by division into 3 geomorphic units:

1. The southern unit extends north from the contact with older Mesozoics to the northernmost westward extension of the Liberator ridges.

This area is characterized in the interstream areas by numerous rubble traces of a conglomerate facies. It is of typical graywacke conglomerate type, maximum thickness is about 200 feet, and the exposure in synclines suggests that not over two such sequences are present in this region. A system of large symmetrical chevron folds, with 30°-50° dips, are superimposed on a regional synclinorium. Low 10°-30° dips roughly outline the major trough axis. Strike is roughly east. Shale and interbedded massive sandstone comprise the bulk of the section.

2. The middle unit lies between the northernmost lateral extension of the Liberator ridges and lat. 68°56'N.

Stratigraphic and structural information here is limited almost entirely to exposures along the Kiligwa River. A new lithologic unit characterizes most of this area. There is a marked difference in bedding characteristics in the interbedded sandstones. Whereas even bedding is prevalent in other areas of Torok formation, the bedding planes in this area are very uneven and the sandstone interbeds are very cross-bedded and ripple-bedded. Strand markings, ripple markings, scours, and other features of shallow-water deposition and current action are present. The general east strike prevails, but dips are much steeper (50°-70°) than those to the south. Overturned dips were noted, the chevron fold pattern is much sharper, and numerous small high-angle reverse faults are apparent. Some southward overturned folds were observed but these are thought to be drag folds on the larger secondary structures.

The structural history of the southern and middle units is complex. Major structures primarily seem to be broad and open. Superimposed upon these are secondary anticlines and synclines, which in turn may have drag and/or chevron folds on their flanks. Repetition of section is common, and errors in quantitative thickness computation are difficult to avoid.

Northward the section becomes more shaly. South dips predominate, and are markedly steep. Overturned beds are rare, but are readily recognized. Pyritic nodules characterize the lower sections, and occasional large pyritic nodular concretions are observed. The axis of a general anticlinorium is placed at lat. 68°54.3'N. on the Kiligwa River where a 50-foot section of what is thought to be the lower siltstone-shale unit of the Torok formation crops out. A reverse fault of some 1,500 feet stratigraphic downthrow lies immediately to the north.

Two miles north of this inferred axis is a general transverse fault zone. Adjacent tributary streams are structurally controlled by the fault zone, and dips are markedly discordant along the strike across the river. The en echelon fault planes strike N.40°E. Evidence is not conclusive but indicates relative movement of the west block to the north. As the fault apparently extends southward across the axis of the anticlinorium, the axis would be offset northward in the western block.

A fossil locality yielded several ammonites; positive identification has not been made but they appear similar to the genus *Lemuroceras*, an ammonite thought to characterize basal sections of the upper Torok formation.

Northward from this zone a radical change in structure was noted. There is an abrupt change from the characteristic steep dips, sharp reversals, and small reverse faults to small open structures. Dips are 10°-40°.

Stratigraphic and structural information along a tributary stream showed this altered dip pattern, and a general correlation of structure along a N.85°W. strike is postulated.

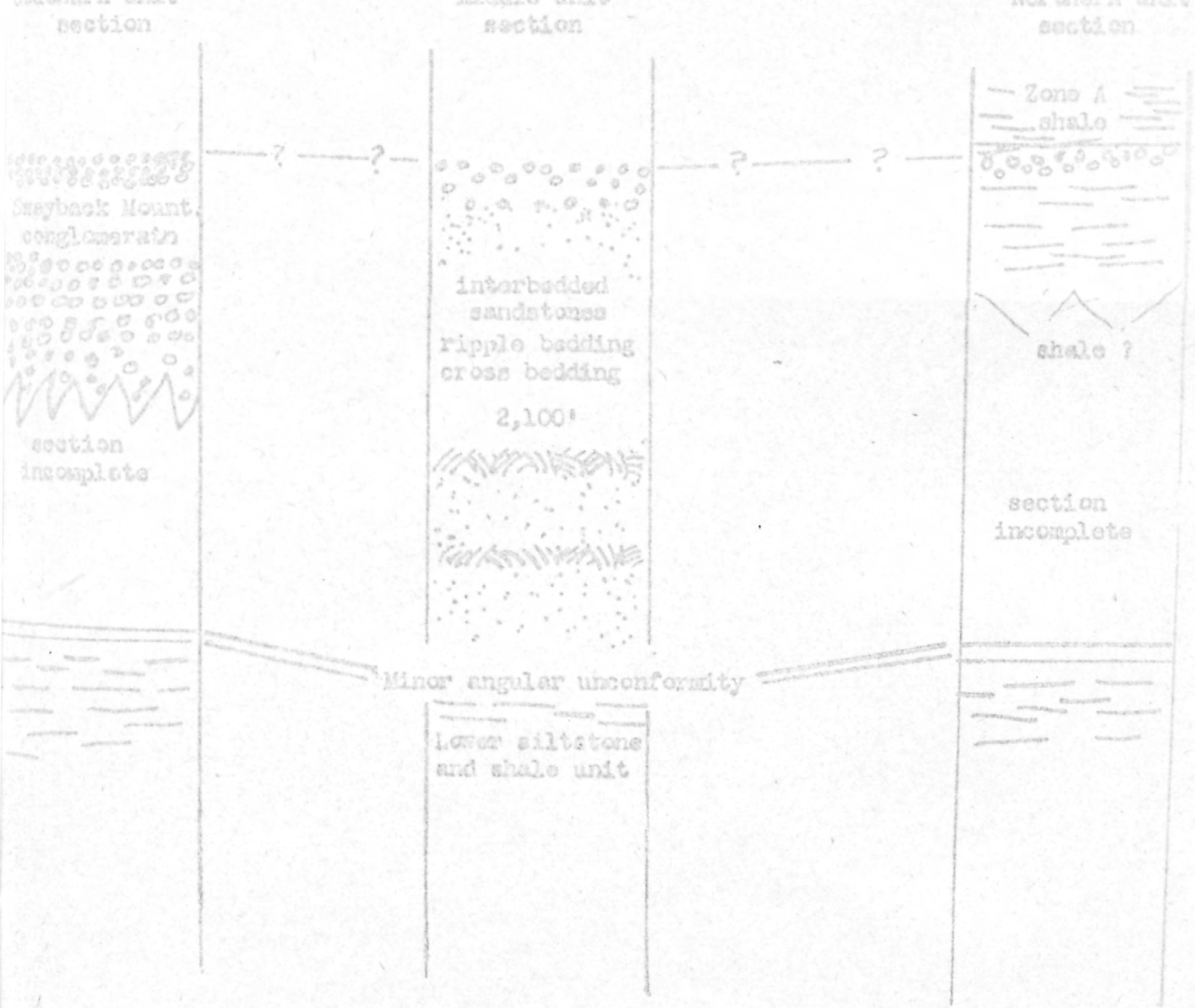
The northern structural phase of this area returns to a 30°-50° dip. Structures are anticlinal. A fossil locality occurs near the center of a small anticline slightly overturned to the south. Here within a general shale section four separate coquinoid beds occur in a 20 foot zone. The well preserved fossils have been identified as *Aucella crassa*. The range of *Aucella crassa* is considered to be Upper Jurassic-Lower Cretaceous (lower part). From the available structural and stratigraphic information, this anticlinal zone probably is a secondary structure. However, because of the nature of the crenulated shale involved and the general lithologic similarity of Lower Cretaceous strata, it is possible that major faults and steep dips expose older sections. The Brady anticline, as mapped by photogeologists, passes through this general area. Crenulated shale sections predominate, but they are not similar to the lower siltstone-shale unit.

3. The northern unit begins at lat. 68°56'N. at the apex of the first large "horseshoe" bend in the Kiligwa River; here a pronounced change in lithology is apparent. Massive sandstone lenses crop out. Fifteen feet of fine- to medium-grained, winnowed, light-green sandstone with carbonaceous material and silt inclusions is succeeded northward by a narrow zone of crenulated overturned beds, and then by an interbedded series of ripple-bedded, cross-bedded, somewhat laminated light medium green sandstone and thin-bedded dark-gray shale.

Thirty feet of conglomeratic beds contain unidentified poorly preserved fossils and fragments in the matrix; in general the lithology compares favorably with upper conglomerate section at Ekakevik Mountain. An estimated 250 feet of fine- to coarse-grained, light-colored, massive sandstone, with laminations, cross bedding and silt inclusions, is interbedded with lighter-colored shale; it overlies the conglomerate and extends to the northern limit of exposure.

The stratigraphy of the Torok formation reflects primarily local and regional facies changes. A diagram may best summarize the fundamental facies changes postulated and is shown on the following page.

The middle unit (2,100 feet) is primarily a facies change of the lower sections of the Upper conglomerate member. Uppermost conglomerate sections are more persistant and may correlate with the conglomerate of the northern regional unit. This conglomerate also marks the base of the Upper Torok.


Southern unit section
Middle unit section
Northern unit section
Zone A shale
Swayback Mount. conglomerate
interbedded sandstones ripple bedding cross bedding
2,100'
shale ?
section incomplete
section incomplete
Minor angular unconformity
Lower siltstone and shale unit

It is proposed then to consider: the lower shale and siltstone as the Lower Member of the Torok formation; the conglomerate and its equivalents as the Middle Member in the northern unit, and the section above as the Upper Member.

A broad anticlinorium structure is outlined. The identification of Aucella crassa in a coquina outcropping in the lower Kiligwa River in this area makes it an attractive prospect for a Lisburne limestone test. If Aucella crassa is a reliable index fossil of the middle Okpikruak formation (Lower Cretaceous), the probable depth to the Lisburne would be approximately 4,000 feet, or possibly 5,000 feet maximum.

THE STRATIGRAPHY AND STRUCTURE OF THE

IPNAVIK RIVER

Work was begun at the Range front where strata of the Kayak formation underlie the Lisburne limestone in the frontal hills and extend northward 1 to 3 miles under a partial pediment surface. Remnants of north-trending ridges expose a gently north dipping sequence of the Kayak formation and lower Lisburne. A minimum of 700 feet of Kayak formation is demonstrated; a thickness of 1,500 feet is indicated. The rocks are dominantly slightly metamorphosed argillaceous claystone and siltstone with abundant finely divided mica that produces a sheen on slaty cleavage surfaces. Dark color predominates but dark to medium gray is common. The lower part of the sequence contains scattered 1- to 3-inch beds of fine-grained quartzite, medium gray in color but spottily stained by oxidized iron. Several 10- to 20-foot zones with a maximum of 50 percent quartzite occur near the middle of the section.

The upper contact with the Lisburne appears gradational through about 50 feet in which several 1- to 2-foot beds and zones of dark yellow-red-weathering limestone are interbedded with 5- to 15-foot shale zones. The shale becomes progressively less metamorphosed, more calcareous, and more carbonaceous upward through the gradational zone. Abundant brachiopod remains were collected.

At least 500 feet of Lisburne limestone overlies the shale and interbedded limestone; a covered interval allows the possibility of at least 800 additional feet of Carboniferous section. The lower 100 feet, above the gradational contact zone, consists of hydroclastic limestone interzoned in 10- to 15-foot beds with black, calcareous shale. The basal zone is a 10-foot bed of medium granular, light-colored crinoidal limestone that contains numerous brachiopods. The overlying limestone zones are less massive and finer-grained; shaly bedding is common. The fossil remains are similar to those contained in the Wachsmuth member of the Lisburne.

Interbedded dark hydroclastic limestone, partly silicified, black shale, and dark to black chert comprise the remaining 400 feet of exposure. The lithology compares best to the Kiruktagiak member. Although a discordance of attitude and greater deformation in the dark-colored strata were recognized, large-scale faults are not known. The Kiruktagiak facies may here have supplanted the limestone facies of part of the Wachsmuth member.

Roughly 100 feet of Triassic-Shublik formation are exposed on the north projection of the ridge. They are the typical buff-weathering medium-gray chert and dense silicified limestone. Another 100-foot zone of chert, dark gray to dark olive in color, in 2- to 6-inch beds and ferruginous in part, overlies the Triassic. Faunal control is lacking but the beds are believed to be Jurassic. The chert underlies a 320-foot section of interbedded siltstone, very fine-grained sandstone, and silty shale. The rocks are predominately dark green and appear to have a subgraywacke character. Coarser sand is obviously quartzose and two conglomerate zones with silicic igneous rock cobbles crop out near the top of the section in a general upward coarsening.

A computed 1,200-1,300 feet of chert, generally dark gray and glassy, overlies the above. Float of red- or green-weathering, earthy-textured chert (silicified silt) and some olive-drab sub-glassy chert occur in the upper part. The series is expressed only as a high ridge of rubble; its attitude is indeterminate.

Another computed thickness, 2,100 feet of sandstone, is present above the thick chert. It is capped on the north end of the long ridge by a thin chert zone that lies immediately below a thick igneous sill. The attitudes of the sandstone and sill are similar and appear conformable. The sandstone is very fine grained, dense, well-indurated, generally calcareous, and is dark gray or dark green. Some silt-shale float appears in rubble from the lower half of the section; approximately 50 percent dark clay-silt shale is present in the upper half. No fossils or fragments were found. The generally high degree of induration, fineness of grain, and evenness of bedding argue against correlation with the Okpikruak formation, which would seem to be the most logical correlative horizon.

The igneous sills overlying the sandstone extend northward 5 miles and westward for at least 8 miles. The northern and western limit appears to be a fault contact with strongly deformed Paleozoic and Mesozoic strata. The series of sills occupies a broad synclinal basin, somewhat broken by high-angle faults. At the southwestern margin of exposure, Lisburne limestone conformably underlies the mafic intrusives; at other places, these intrusives are underlain by undifferentiated chert. These intrusives lie in the same latitude as the massive sills in the De Long Mountains to the west, and also directly south of the sill-intruded Lisburne limestone series described on the Ipnavik "thrust sheet" in 1950 7/.

Details noted on the traverse through the area mapped in 1950 are:

1. The Okpikruak formation occurring on the broadly folded "thrust sheet" is in contact with chert of the Lisburne limestone on the south edge of the sheet. An unconformity is demonstrated in which the angular discordance (over a distance of 8 miles) is sufficient to have Jurassic and Triassic rocks in contact on the north edge and Mississippian and Okpikruak formation on the south edge.

2. On the Ipnavik River, along the axis of the syncline which forms Ekakevik Mountain, the basal beds of the conglomerate series of the Torok formation lie, with no apparent discordance, on Okpikruak formation. The lower shale unit of the Torok formation appears to be absent. This corroborates the presence of an unconformity between the upper conglomerate and lower shale units of the Torok formation that was noted in 1950 farther east.

3. At the north edge of the complex, several incomplete sections of Jurassic beds are present. At one locality 120 feet of dark clay shale overlies Triassic chert and cherty limestone and are capped by a sill 50 to 75 feet thick. The shale is poorly indurated, slightly calcareous, poorly

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7/ Tailleur, Irvin L. and Kent, B. H., op. cit.

stratified. The fresh dark color weathers green and hematitic red. Exposures of the shale are rapidly reduced to clay banks. One 6- to 8-inch bed of coquinoid limestone occurs within 15 feet of the lower contact and another occurs at the 100-foot level. Aucella bronni comprise the coquina and have been identified as Jurassic (Oxfordian).

A quarter of a mile south of the above section, 35 feet of black brittle calcareous shale, and black bedded chert overlie the Triassic limestone and chert. Impressions and silicified remains of pelecypods occur in the chert. Six feet above the chert-shale beds a coquinoid limestone is present in a shale bank.

A section of a few hundred feet of graywacke-type siltstone and shale with zones of pyritic dark chert and paper shale are also associated with the Shublik formation. The relationships to the strata containing Aucella bronni are indeterminate.

The Torok formation is exposed in discontinuous cut banks along the lower Ipnavik River where the river crosses the plain north of the Foothills complex. No lithologic units are present that serve as definitive stratigraphic markers. The structure is so complicated that few reliable projections or thickness estimates are possible.

At least three lithologic divisions may be made. The boundaries between units are not sharp, and each division is variable in lithology.

The lower unit, consisting of several hundred feet of siltstone and shale in varying proportions, is present in the most southerly zone of cuts. The siltstone is dark-gray green, locally calcareous, and distinguished by rippled and curly bedding caused by current action or slumping. The shale is generally silty, dark, and evenly though variably bedded. Exposures of the unit are somewhat distinctive in that the interbedding is fairly regular and commonly produces "ribbed" outcrops.

Along the southern area of Torok formation exposure, the middle unit, an undetermined thickness of shale, clay, and silt, gradationally overlies the lower siltstone-shale unit or occurs without observable relationship to that unit. Only a minor amount of siltstone is present, and distinctly even bedding is characteristic.

Near the mouth of the Ipnavik River another lithologic unit overlies the siltstone-shale. The lower 100 to 200 feet consists of evenly bedded, flaggy weathering, fine-grained subgraywacke sandstone. This grades upward through lighter-colored, less well cemented sand into a dominantly shale section. Although differing in lithology as well as in geographic position, similar stratigraphic positions indicate a tentative correlation.

The upper lithologic unit is best developed on the eastern end of the east-flowing part of the river. Here 1- to 10-foot massive beds of medium-gray, fine- to medium-grained sandstone are present in a clay shale sequence.

The sand appears to be somewhat winnowed; it contains horizons of carbonaceous fragments along even bedding planes in the middle of the beds and carbonaceous concentrations in the troughs of ripple marks on the tops of beds. Most of the sandstone weathers lighter than siltstone beds elsewhere and forms more irregular patterns in stream cuts than the rhythmically bedded siltstone does. Some of the thicker sandstone beds weather a distinctive light-yellow red. Perhaps of greater stratigraphic significance is the dominantly argillaceous composition of the shale. Lack of prominent bedding is also distinctive; some of the beds between massive sandstone beds are claystones that weather conchoidally. Where the sandstone is absent, evenly bedded siltstone alternates irregularly with the clay shale, but in lesser proportions than in the siltstone unit proper.

Another criterion of this unit is the relative concentration of fossils. However, this is not conclusive evidence.

The mapping of unit contacts was largely arbitrary. In some places, stratigraphic determinations are contradicted by local structure. Faults are probably prevalent throughout the area and may account for many of the discrepancies.

Little structural speculation is possible. Except for the open fold of the upper unit near the mouth of the river, the degree of deformation is surprisingly constant. Minor sharp folds are present in the shale and siltstone units in the south. Axes of some of the small folds substantiate the presence of broader (1 to 3 mile) structures outlined on the basis of lithology. Northward overturning of beds is common in the southern area, perhaps less so along the middle part where bedding attitudes suggest less intense folding.

The small fold axes or reversals shown on the map represent asymmetric folds that range from 200 to 500 feet across. The larger structural axes along the middle part are postulated mainly on the basis of lithology. The persistent structural grain is N.70°W. Local variations probably result from plunge of the larger structures. What information was noted indicates a flat east plunge of the structures.

Structural evidence suggests the presence of a large structural high near the middle of the lower Ipnavik River area.

CONCLUSIONS

Structural and stratigraphic evidence is inconclusive. The presence of an anticlinorium is not definitely established, but the presence of a significantly large structure is not disproven. All evidence considered, a regional reversal is suggested, with the crestal region at lat. 68°50'N. The outcrops there appear to be low in the Torok section, perhaps near the base.

The area may be promising for testing the Lisburne limestone. The presence of a fairly thick dolomitic phase in the Lisburne Ridge 16 miles to the south shows that favorable reservoir conditions exist in the Lisburne limestone nearby; projection of these conditions to depth under the Ipnavik should be reasonably safe. A conservative estimate of depth to the Lisburne must include the total observed thicknesses of all units underlying the Torok formation, plus a margin for possible thickening of the section, and plus the maximum postulated thickness of the Torok formation remaining in the crestal area. Thus 2,000 feet of Torok; 3,000 feet of Okpikruak and lower Torok, shale unit; 1,500 ± feet of Jurassic (no control in the foothills, but 1,500 ± feet indicated at the Range front); and less than 1,000 feet of Triassic and uppermost Paleozoic give a total of 7,500 feet as a reasonable maximum depth to the Lisburne. A variable factor is the thickness of the Torok formation, which is 6,800 feet in aggregate thickness in the Etivluk-Kiligwa Rivers area but less than 5,000 feet is exposed at any one locality. The upper 1,000-2,500 feet of the formation has certainly been removed from the Ipnavik River area. If this upper part is not considered in estimates for the Ipnavik River area, the maximum thickness of the Torok is reduced to 4,500 to 5,000 feet. As the lower Torok is included with the Okpikruak in the estimate, the maximum Torok thickness is further reduced to 3,500-4,000 feet. It is possible, then, that less than half the middle Torok remains in the Ipnavik River area. The 3,000 feet of Okpikruak-lower Torok shale unit should thin northward. Little speculation on the Jurassic is possible. The 1,000-foot estimate of Triassic and uppermost Paleozoic is also high, as that sequence is represented by about 500 feet at the Lisburne ridge. Numerous unconformities, with consequent removal of section, have been noted: post-Triassic, intra-Jurassic, post-Jurassic, post-lower Torok shale unit, and within the upper Torok. Whether these unconformities, largely local in nature, effected thinning of sections as far north as the Ipnavik River is a question. The predicted depth may be reasonably decreased by 1,500 feet, not considering the possible thinning of the Jurassic or further decrease that may be caused by unconformities.

If the subsurface top of the Lisburne limestone conforms to the configuration of the regional reversal, in its minimum development the structure would be too broad for satisfactory closure or localization of highs. However, closure may be indicated by: (1) the Lisburne Ridge, 16 miles south, is a relatively narrow fold with vertical beds on the north flank and beds dipping 70° on the south flank; (2) the regional reversal is on the order of Namushuk structures; the Torok at the surface is folded more intensely than seems reasonable on the basis of incompetency alone; (3) structural and stratigraphic highs were developed during Torok time on the north margin of the Foothills complex; some manifestation of this deformation would be expected to the north; (4) a suggested pre-Permian warping seems to have a regional aspect; (5) the structural history of the area immediately south includes, in part, recurrent movement along early trends. Instead of absence of satisfactory structure at depth, the reverse may be true.

The possibility is great, therefore, that the Lisburne is present at attainable depths and with favorable reservoir and structural conditions. The surface expression is too broad and information too meager to permit limiting a test area with any assurance that such a test would be conclusive. An added difficulty is that surface data may not be indicative of subsurface conditions.