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Study and Correlation of Belt and Cambrian Arkoses near Limespur, Montana

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Ryan C. McNamee

A Thesis
Submitted to the Department of Geology
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Photograph of hillside near Limespur where the Belt-Cambrian arkose problem was discovered. A fold involving Belt and Cambrian arkoses occurs on this hillside in the area covered by sage brush.

STUDY AND CORRELATION OF BELT AND CAMBRIAN ARKOSES NEAR LIMESPUR, MONTANA.

INTRODUCTION

In the vicinity of Limespur, Montana, a siding along the Northern Pacific Railroad near Whitehall, Montana, occurs a characteristic type of arkose wherein many small red mineral grains are distributed throughout the rock mass. It is in this respect that this arkose differs from other arkoses in the surrounding region, the others being more uniformly gray and green. All arkose has in earlier studies been considered pre-Cambrian (Belt) in age. It is now known that "red-specked" arkose and arkosic limestones occur in a Cambrian formation (Wolsey) associated with fossil forms (Trilobites). The purpose of this study, which was undertaken to fulfill requirements for undergraduate thesis work at the Montana School of Mines, is to attempt to establish the relationships of these arkoses, and explain the presence of an arkose similar to pre-Cambrian arkose within a Cambrian formation.

While the pre-Cambrian series in Montana has been studied extensively by Dr. C. H. Clapp and others, very little attention has been given to the arkosic series near Limespur. The author has been able to find only two references concerning this series.[1] No reference at all has been found concerning the Cambrian arkose with which this paper deals. The area immediately

1. Tansley, W., Schafer, P. A., and Hunt, L. H., "A Geologic Reconnaisance of the Tobacco Root Mountains", Montana Bureau of Mines and Geology, Memoir #9.
   Peele, A. C., U.S.G.S. Atlas 24, Three Forks Folio, 1896.

surrounding Limespur has been mapped twice. The first mapping was done by A. C. Peele in the service of the U.S.G.S. in 1896. The second mapping was done by members of the senior class at the Montana School of Mines in September 1937, at which time the Cambrian arkose first came to light.

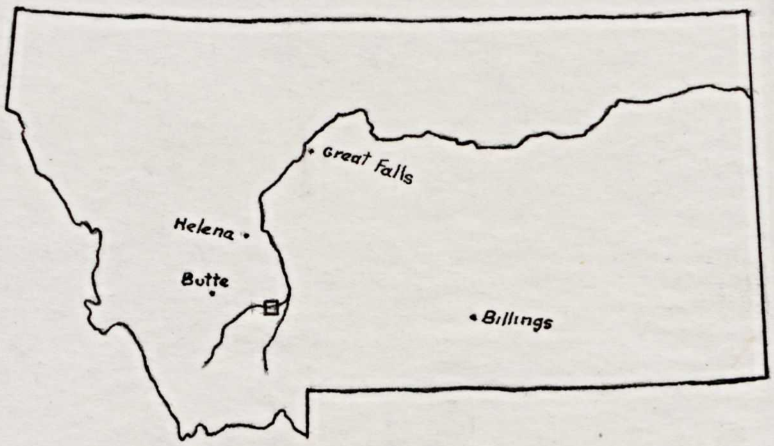


Fig. 1 Index map of Montana showing location of area under consideration.

Limespur, Montana, lies in R2W, T1N, S19. More generally, it is about 14 miles east of Whitehall, Montana, on U.S. highway No. 10. The area is easily accessible. The Northern Pacific Railroad, and also U. S. highway No. 10 along which there is regular bus service, pass through Limespur, and two roads from the highway to Morrison Cave (Lewis and Clark National Monument) bring the greater part of the arkose outcrop within easy reach.

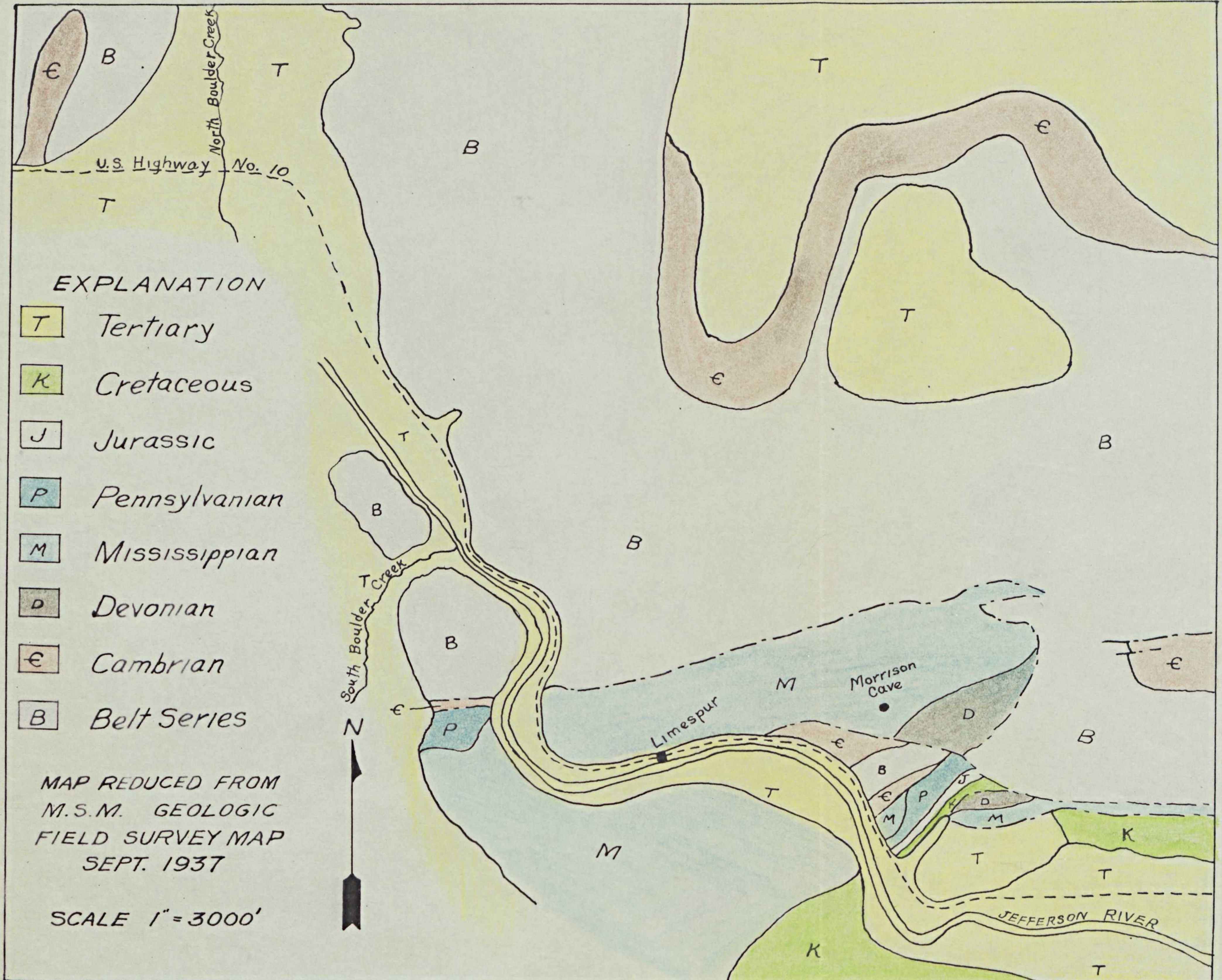
The area surrounding Limespur is high and semi-arid with a maximum relief of about 2000 feet. The Jefferson River, North and South Boulder Creeks, and a network of intermittent streams form the drainage system for the region. Annual precipitation is from 10 to 15 inches, and the annual temperature range from 90° F. to -30° F. Vegetation is scarce, the only growth being such as sage brush, bunch grass, scrub pine, cottonwood and box-elder trees.

The writer wishes to acknowledge, with greates appreciation, the many valuable suggestions of Dr. E. S. Perry both in the field work and in the preparation of this report, and also for help in laboratory studies, to Dr. L. L. Sloss for his advice and help in the study of fossils, and to Dr. Geo. A. Seager for his aid and many suggestions in the petrologic studies. Geo. A. Johnston, an undergraduate at the Montana School of Mines, measured the sections shown in the text at a time at which the author was unable to do so, and was the source of many valuable suggestions in his discussions of the problem with the author.

GENERAL GEOLOGY OF THE AREA

The rocks exposed in the vicinity of Limespur represent an almost complete geologic section. With the exception of the Ordivician and Sillurian periods, rocks of every period are present. The oldest exposure in the area is that of Archaen gneisses. These are unconformably overlain by the Algonkian Belt series. Another unconformity separates the Belt series from middle and upper Cambrian formations and these are in turn separated from Devonian formations by an unconformity which cuts out the Ordivician and Sillurian rocks. Upwards from the Devonian there is a quite complete section of sedimentary rocks interrupted only in the upper Cretaceous by lava flows. Extensive deposits of Bozeman Lake Beds (Tertiary) are found in the area.

From the standpoint of geologic structure, the area is quite interesting. Major and minor faulting together with considerable folding has greatly disturbed the strata and has introduced numerous complications. There are two major faults in the area each with a vertical displacement of approximately 10,000 feet. In addition to these and probably closely connected with



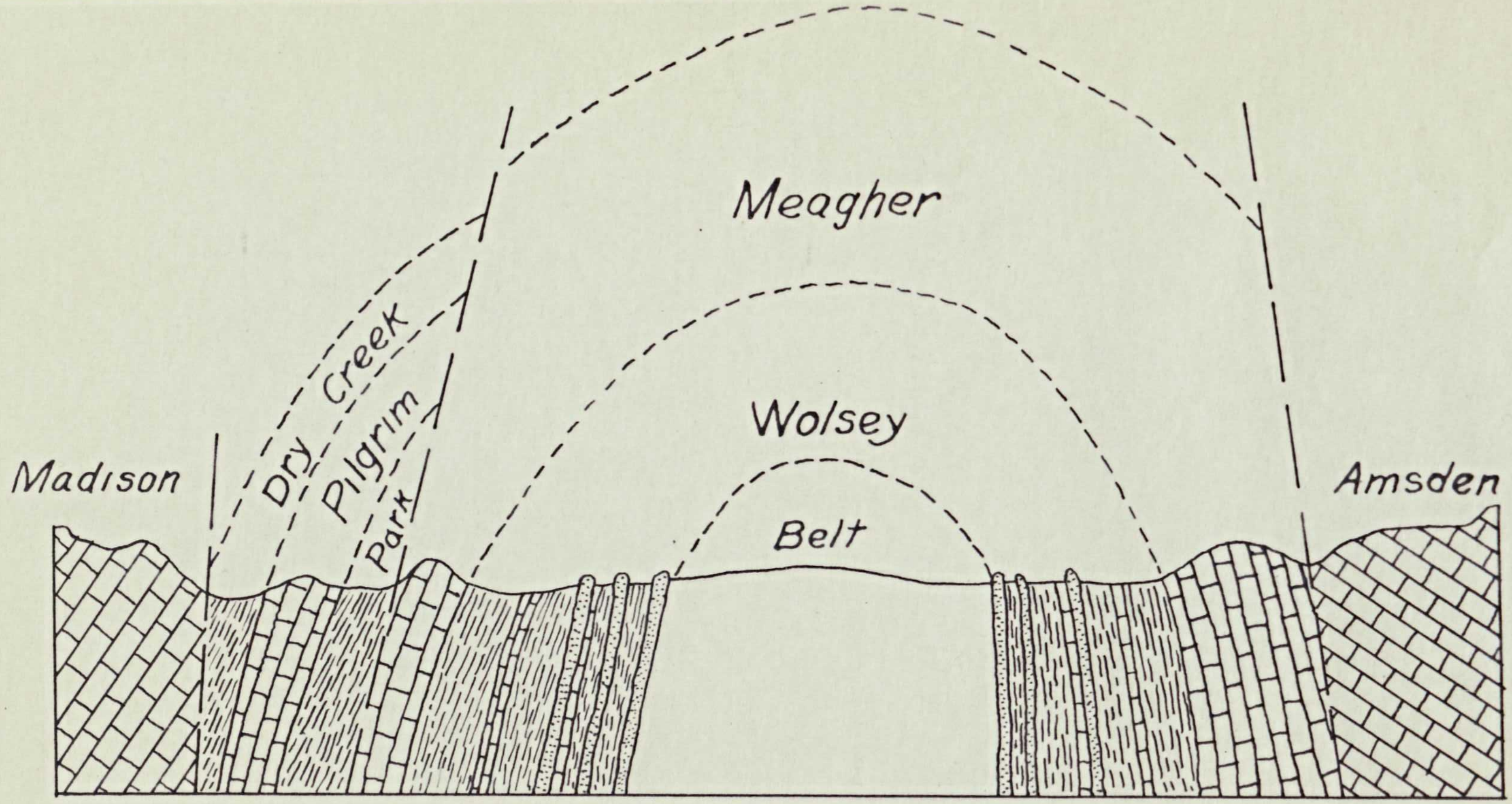
GEOLOGIC MAP OF VICINITY OF LIMESPUR, MONTANA them are numerous smaller faults. Considerable folding has taken place and has in spots so complicated the structure that mapping is most difficult.

The geologic history of the area is comparatively simple. Archean rocks after deposition were severly metamorphosed and peneplaned. The Belt series was deposited on this peneplane and then folded and faulted slightly but remained unmetamorphosed. These were then subjected to a very long period of erosion. During the Paleozoic there were many minor oscillations of the surface. This condition continued until late upper Cretaceous at which time there was a general elevation and deformation of the region. The only activity since has been the deposition of lake bed deposits, terrace gravels, and alluvium.

OCCURRENCE OF THE ARKOSE

The geographic occurrence of the Belt arkose in the vicinity of Limespur is shown on the map, (Plate 2). Near Limespur, the formation owes its appearance to normal faulting with displacements as high as 10,000 feet. Farther northward and also to the east, the Belt is in normal contact with Flathead quartzite. Almost everywhere that the Belt arkose occurs in the vicinity of Limespur, it forms steep hills. Sharp gullies cut by intermittent streams are numerous in this formation. In the northeast corner of the area shown on the map, (Plate 2), the arkose levels slightly to form a rather flat upland.

One mile east of Limespur on U. S. highway No. 10 there is a fold involving Belt and Cambrian formations. It is at this spot that the problem with which this paper deals was discovered. (Plate 1). Here, the Belt and Cambrian arkoses are found together. Belt arkose occupies the center of the fold and grades outward into Wolsey arkose, shale, and limestone.



PL. 3 —DIAGRAMATIC SECTION THROUGH FOLD INVOLVING BELT AND CAMBRIAN ARKOSES.

(AUTHORS INTERPRETATION)

The Meagher limestone flanks the fold on both sides. (Plate 3).

STRATIGRAPHIC POSITION OF THE ARKOSES

In the normal geologic section for the area in which Limespur is situated, the Belt series underlies middle Cambrian formations the lowest member of which is the Flathead quartzite. The Wolsey shale lies immediately above the Flathead quartzite and is considered transitional between the Flathead quartzite and the Meagher limestone. Under normal conditions the Flathead quartzite and Wolsey shale always occur together. The normal section measured in South Boulder Canyon, a few miles south of Limespur, is shown in Plate 4.

Examination of the map, Plate 5, shows the great areal extent of the Flathead quartzite. The formation is quite uniform in thickness and its deposition was apparently unbroken over the southwestern part of Montana, where it forms the basal member of the Cambrian. This normal condition is upset in the forementioned fold involving Belt and Cambrian arkoses. Here, the Flathead quartzite is not present in its normal position between these two formations. Furthermore, there is no apparent line of demarcation between the two arkoses.

CHARACTERISTICS OF THE ARKOSES

Lithology

Belt Arkose

The exposure of the Belt series in the vicinity of Limespur differs lithologically from the typical section in the northwestern part of the State. While the section has not been measured, it is estimated to have a thickness of about 10,000 feet. The upper half consists of a very fine grained rock which has the appearance of shale but which, according to

COLUMNAR SECTION OF THE SOUTH BOULDER AREA

Scale 1" = 1000'

Period	Formation	Sym	Columnar Section	Thickness	Character of Rock
Tertiary	Volcanics	T_v		3000+	Andesites - Basalts Agglomerates
Cretaceous	Colorado	K_c		180	Shale
	Dakota	K_d		430	Limestone Sandstone
	Kootenai	K_k		450	Shale Sandstone
Jurassic	Morrison	J_m		390	Varigated Shale
	Ellis	J_e		100	Limestone Shale
Permian	Phosphoria	P_p		50	Oolitic Phosphate
Penn.	Quadrant	P_q		240	Limestone - Quartzite
Miss.	Amsden	M_a		340	Limestone 30-40 Red Shale
	Madison	M_m		1800	Crystalline Massive Limestone Fossils
Devonian	Three Forks	D_{tf}		800	Green Shale Fossils
	Jefferson	D_j		1300	Massive Limestone with Dolomite Bands
Cambrian	Dry Creek	$Є_{dc}$		90	Green Shale
	Pilgrim	$Є_{pi}$		70	Mottled Limestone
	Park	$Є_{pr}$		370	Green Shale
	Meagher	$Є_m$		530	Limestone Oolitic - Trilobites
	Wolsey	$Є_w$		200	Green Shale
	Flathead	$Є_f$		250	Quartzite
Pre-Cambrian	Belt	$pЄ_b$		5000±	Shales & Arkoses
	Pony			?	Schists & Gneisses

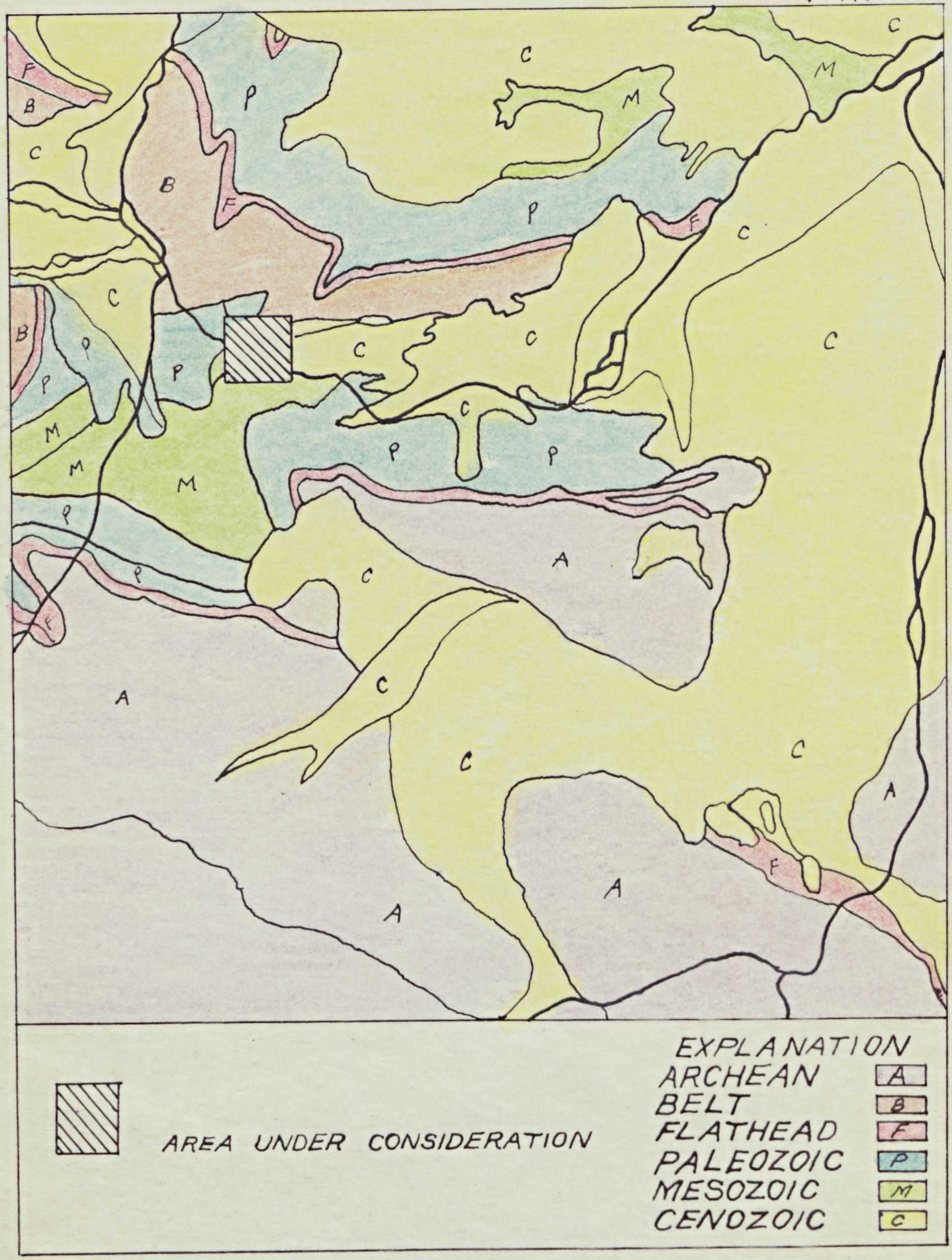
Tansley, Schafer, and Hart[1], proves to be essentially an arkose upon microscopic examination. The lower half is an arkose ranging in grain size from sandy to conglomeritic, and consists of grains and pebbles of crystalline limestone, quartzite, gneiss, and pegmatite. The mass seems unsorted as a whole but bedding is distinguishable in most places. The pebbles of the more conglomeritic part may be one foot in diameter. Certain phases greatly resemble mud flows. (Plate 6). This exposure of Belt arkose is believed to be a shore-line deposit especially since it thins abruptly eastward and is absent 15 miles to the east.

This arkose was first described by A. C. Peele[2] thus: "--- coarse sandstones and conglomerates, whose arkosic character is evident. They are of somber hue, dark green and steel gray colors predominating." For the greater part of the exposure this description is correct. However, there are large exposures of arkose which are decidedly red. It is interesting and pertinent to note that, while in the valley bottoms the arkose is of a decided green color, it grades on up to red at the tops of the hills. Also, boulders in the valley bottoms which are red on the outside, show green on a fresh fracture and actual weathering rims can be seen.

Cambrian Arkose

The Cambrian Arkose would probably be more properly referred to as a calcareous arkosic sandstone. It is made up essentially of quartz and felspar and is typically reddish in color. Bedding is very distinct, especially so because of the fact that it is interbedded with shale and limestone. Some of the arkose beds are decidedly limey, and it is in these beds that

1. Idem: - p 12
2. Idem: - p 2



GEOLOGIC MAP SHOWING DISTRIBUTION
OF FLATHEAD QUARTZITE NEAR LIMESPUR
(AFTER U.S.G.S. FOLIO 24)

trilobite fragments are found. The trilobite zones themselves differ. Some are only slightly limey and contain only a few fossils, while others are almost a coquina of trilobite fragments scattered through with grains of calcite, quartz, and feldspar. Apparently the arkose is a quite resistant rock because it forms prominent walls up the side of the hill on which it was found. The following sections of Wolsey were measured[1] on the fold involving Belt and Wolsey formations:

(1) Section measured across Wolsey on east side of fold measuring outward from contact with Belt arkose.

Green micaceous shale..........................	7 feet
Loosely consolidated brick-red arkose........	5 "
Limey brownish-green shale...................	5 "
Limey arkose (ripple marked)..................	6 "
Basic igneous dike............................	2.5 feet
Limestone and coarse arkose..................	4 "
Basic igneous dike............................	0.5 "
Limestone and coarse arkose..................	4 "
Thin-bedded arkose and green shale...........	5 "
Thin-bedded arkose and limestone.............	2 "
Green micaceous shale.........................	106 "

(2) Section measured across Wolsey on west side of fold measuring outward from contact with Belt arkose.

Fine grained red arkose......................	88 feet
Thin-bedded limestone with red specks........	8 "
Thin-bedded green shale and limestone........	14 "

[1] Section measured by Geo. A. Johnston, Montana School of Mines, March, 1938.

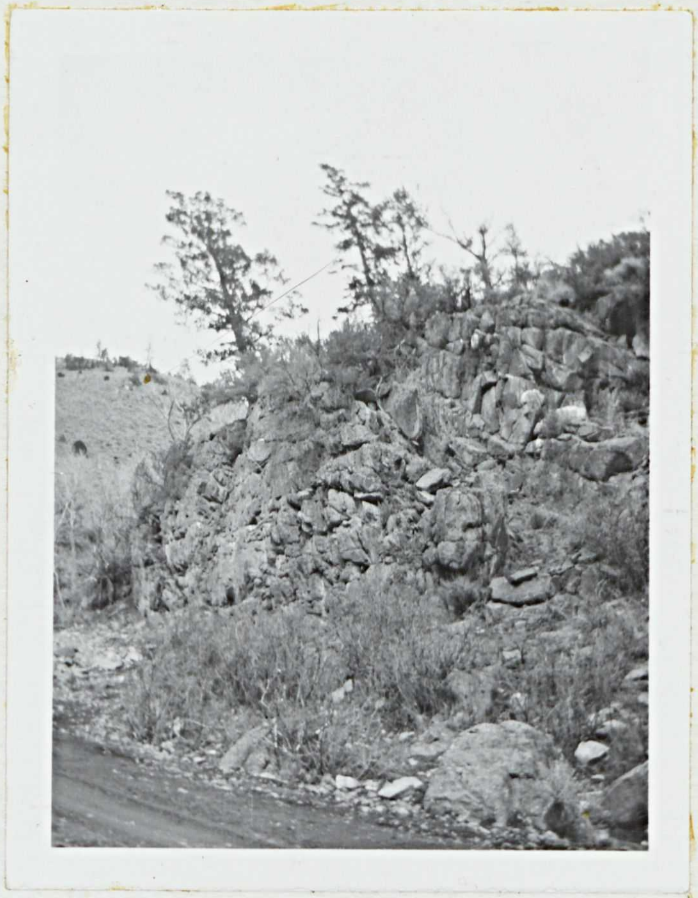


Plate 6
Outcrop of Belt arkose on road cut. This particular outcrop plainly shows structure resembling mud flows.

Limestone with thin bands of shale............... 20 feet

Green micaceous shale
(covered with limestone talus)......... ?

Petrography

Thin-section studies of the two portions of the Belt arkose were made of the fine grained zones for obvious reasons. All of the Cambrian arkose was sufficiently fine grained for thin-section study.

Green Belt Arkose

Petrographic study of the green portion of the Belt arkose showed the following percentages of minerals: chlorite, 70%; quartz, 15%; minor percentages of microcline-microperthite, plagioclase, hornblend, and fragments of feldspathic sandstones. All grains were angular to sub-angular, and the chlorite, which was present more or less pseudomorphically, showed great tendency to fill interstices. The chlorite is probably present after hornblend because it is present in hornblend pseudomorphs, and because a few hornblend grains in the rock show partial alteration to chlorite. (See Plate 9A).

Red Belt Arkose

The red portion of the Belt arkose is composed almost entirely of quartz and feldspar. Scattered grains of chlorite partly altered to limonite are present. (Plate 9B). Differentiation among the feldspars was difficult due to the fact that most grains of these minerals were soaked with an iron stain--probably limonite or hematite. However, microcline-microperthite, and plagioclase were recognized. Grains were for the most part sub-angular.

Cambrian Arkose

The grains in this arkose are quartz, microcline-microperthite, and

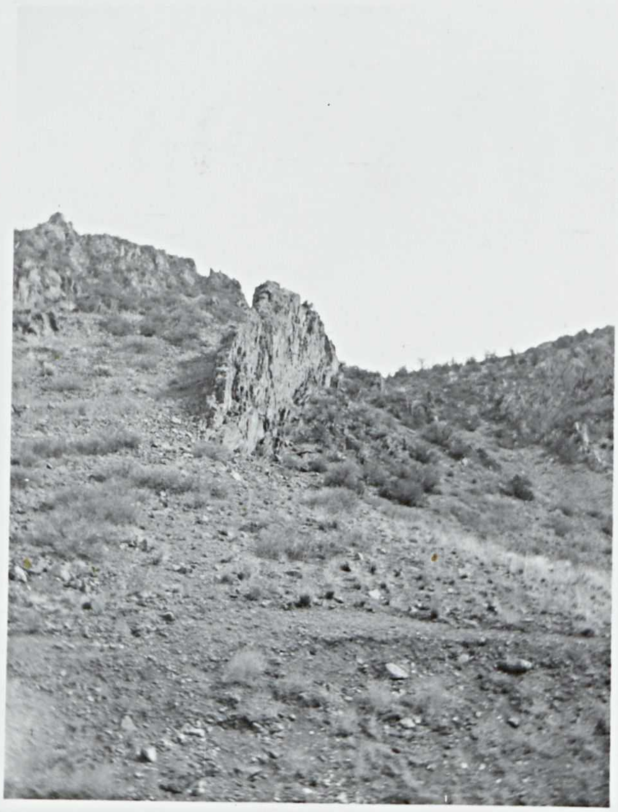


Plate 7
Outcrop of Cambrian arkose on hillside. Soft shale beds on both sides leave this resistant arkose weather out prominently in the form of a vertical wall. Bedding is vertical.

plagioclase. As in the case of the red Belt arkose, the feldspars are soaked with an iron stain of limonite or hematite. (Plate 9 C). The stain appears to permeate the rock through cracks and along grain boudaries. Scattered grains of chlorite partly altered to limonite are present. In those beds which are limey, the grains lie in a matrix of crystalline calcite which may comprise as high as 80 per cent of the rock.

PALEONTOLOGY

Relationships of the Fauna

The fauna found in the Cambrian arkose occurs in the limey beds. These beds range from a few inches to several feet in thickness and are interbedded with shale, limestone, and pure arkose. The limestone is present as a matrix and comprises from 15 to 80 per cent of the rock. In places, the fauna is so abundant as to almost form a coquina.

The fossils consists of fragments of trilobites definitely Cambrian in character. The absence of any distinguishable eyes, the distinctly three-lobed carapace, and the absence of surface ornamentation and excess development of spines all point towards the age of the trilobites as being Cambrian. Furthermore, one species bears a very striking resemblance to Kootenia quadriceps, a middle Cambrian form from Utah. Consequently, while there has as yet been no positive identification of the species found, the general character of the trilobites and their resemblance to known middle Cambrian species leads the author to believe that the fauna is of middle Cambrian age. Furthermore, the stratigraphic position of these strata points rather convincingly to a Cambrian age.

The Wolsey shale near Three Forks, Montana, is an abundantly fossiliferous zone. The forms found in this shale, however, do not compare favorably with the fauna in question. This part of the Wolsey shale contains Ogygopsis, Bathyuriscus, Micromitra, Eodiscus, Agnostus, and primitive brachiopods. None of these forms are recognized in the Cambrian arkose near Limespur. Comparison with the Burgess shale of British Columbia is equally as futile. Forms such as Agnostus, Obolus, Bathyuriscus, Ogygopsis, and Neolenus occur in this shale. With the possible exception of Neolenus, there is no coincidence. Most favorable comparison of the Cambrian arkose fauna is made with fauna from near Ute Peak, Wasatch Range, Utah.

Descriptions

Neolenus

Plate 10A

Known only from a single free cheek and genal spine. Doubtfully referred to this genus.

Kootenia

Plate 10B

Only specimen is a single pygidium. Small and ellipsoidal, with high axial lobe, marked pleural grooves, and six spines on each side. Compares favorably in appearance with Kootenia quadriceps[1].

Idahoia

Plate 10C

Broad frontal limb. No glabellar or occipital furrows. Dorsal furrow well marked and transverse in front of glabella which tapers slightly. Probably an occipital spine.

[1] Hall and Whitfield, U.S.G.S. 40th Parallel Survey, Vol. 4, p 240.

RELATIONSHIP OF THE ARKOSES

In lithologic studies there is one outstanding feature which helps in the correlation of the arkoses, namely, that the green portion of the Belt arkose grades always upward into the red portion. In the valley bottoms the green arkose is exposed, whereas on the hilltops the exposure is almost exclusively of the red arkose. In zones which are clearly transitional between green and red arkose, boulders of apparently red arkose will, on fresh break, show green interiors. This is a true weathering phenomenon and gives one good reason to believe that the red arkose is the weathered product of the green arkose. There are no good lithologic correlations which can be made between Belt and Cambrian arkoses.

In the petrographic examinations, thin-sections of four types of arkose, namely, green Beltarkose, red Belt arkose, Cambrian arkose, and limey Cambrian arkose, were studied. All of these types showed an abundance of quartz, considerable microcline-microperthite, and scattered grains of plagioclase feldspar. Grain size shows a decrease of from 1/25" to 1/50" in the Belt arkose, to 1/50" to 1/100" in the C ambrian arkose. No noticeable difference was noted in the angularity of the grains. Since all of these factors are more or less constant, it remained for the ferro-magnesium minerals in the rocks to supply the means of correlation.

In the green Belt arkose, the ferro-magnesium minerals consist of chlorite and hornblend. Very little fresh hornblend was found. The chlorite in places showed pseudomorphs after hornblend, but was present for the most part as irregular masses. The ferro-magnesium minerals in the red Belt arkose are limonite and chlorite. The chlorite showed definite replacement by limonite, and the limonite showed a tendency to permeate the rock by following grain boundaries and then to apparently completely soak the feldspar minerals present. Limonite is the ferro-magnesium mineral in the Cambrian arkose. Here it is present in exactly the same form as in the red Belt arkose.

The following are the conclusions drawn from petrographic studies: Hornblend was present in the rock from which the Belt arkose was derived. This, upon deposition of the arkose, was altered to chlorite. When the Belt arkose was exposed to superficial conditions, the chlorite started to alter to limonite. Given sufficient time it would become completely altered. The Cambrian arkose was derived from Belt arkose under conditions such that complete alteration of the chlorite to limonite had taken place before the consolidation of the rock.

ORIGIN OF THE CAMBRIAN ARKOSE

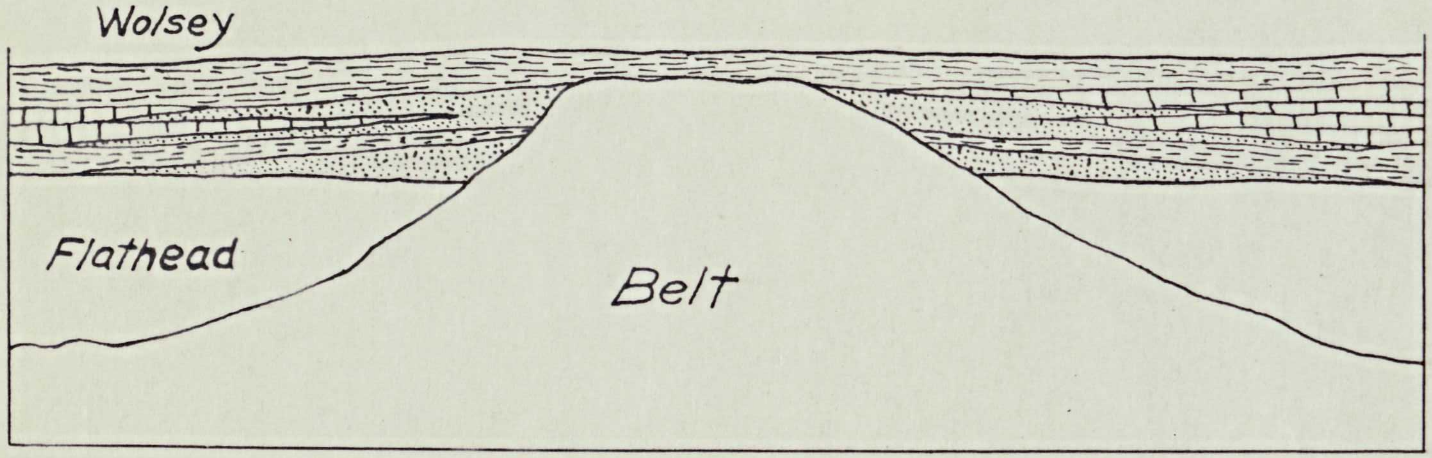
In a discussion of the origin of the Cambrian arkose, there are two chief points to be considered: (1) The Flathead quartzite, while present at the base of the Cambrian in all other exposures in the area, is missing between the Belt and Wolsey arkoses; (2) Petrographic studies lead to believe that the Cambrian arkose was derived directly from the Belt arkose. These considerations condense the problem of origin of the Cambrian arkose to an explanation of conditions which would cut out the Flathead quartzite over a small area, and which would deposit arkose derived from Belt arkose in what were normally shale and limestone depositing conditions.

The Flathead quartzite was laid down on a very flat peneplane of Belt. This fact is quite evident when the great areal extent and uniform thickness of the formation are considered. The problem of the local absence of the Flathead quartzite is open to two possible explanations: (1) That the formation was deposited and later eroded away before deposition of the Wolsey; (2) That the formation was never deposited in the area under consideration. If the Flathead quartzite was deposited, and uplift must have taken place in order that it be eroded away, since there is no sharp break between the Flathead and Wolsey and consequently no recession of the sea at that time.

This uplift could be the result of folding or faulting. This would allow the stripping away of the Flathead and the deposition of Wolsey directly on Belt. This view is open to the following arguments: (1) The time of the deposition of middle Cambrian formations, was not a time of even local disturbances, as witnessed by the conformity and regular occurrence together of the Flathead and Wolsey formations wherever exposed; (2) The Wolsey is commonly recognized as being transitional between the Flathead below and the Meagher above; (3) There are not enough quartzite fragments in the Wolsey shale where they would necessarily have to be if the Flathead was eroded away, because the deposition in the area was continuous. Furthermore, it may not be considered that the Flathead was broken down to grain size, thus giving the quartz grains in the Wolsey arkose, because while the quartz grains of the Flathead are for the most part rounded, those of the Wolsey arkose are angular to sub-angular.

In considering the second possible explanation for the absence of the Flathead, namely, non-deposition, we must assume an upstanding topographic feature on the belt peneplane something of the nature of an island. This feature might be an erosional remnant, a fold, or an upfaulted block. The exact nature is not essential to the problem. This feature would locally cut out the deposition of the Flathead and allow the deposition of Wolsey directly on Belt. There are two main arguments against this view: (1) An upstanding erosional feature would be unlikely on such a complete peneplane; (2) Local folding or faulting, such as required here, has not been observed on the Belt peneplane prior to the deposition of the Flathead at any other point in the area.

Once the absence of the Flathead has been explained, the problem of origin becomes simplified. A small island of Belt arkose protruded above a sea which was depositing shales with bands of limestone. The Belt arkose



PL. 8 — DIAGRAM ILLUSTRATING POSSIBLE MODE OF DEPOSITION OF CAMBRIAN ARKOSE.

was weathered by the action of the sea, and detritus of the weathered product interfingered with the shales and limestones, some being deposited simultaneously, thus producing the shaly and limey arkose beds which occur in the formation. (See plate 8). It may be due to this condition that the Belt and Wolsey appear to grade into each other.

SUMMARY AND CONCLUSIONS

In the vicinity of Limespur, Montana, arkose members are found in both Belt and Cambrian formations. The Belt arkose consists of two apparently different types, one red, and one green. The Cambrian arkose is interbedded and intermingled with fossiliferous shale and limestone beds. The Flathead formation, which is normally present between Belt and Wolsey, is missing in one small area. In this area, where the only occurrence of Cambrian arkose is found, the Belt and Cambrian arkoses appear to grade into one another and are involved in a fold.

The author has reached the following conclusions; (1) That the red arkose is the result of the weathering of the green arkose since recent exposure; (2) That the Cambrian arkose was derived from the Belt arkose, being deposited as red arkose; (3) That an erosional feature on the Belt peneplane stopped the deposition of Flathead quartzite over a small area and was responsible for the exposure of Belt over Flathead therefore producing an arkose derived from Belt in the Wolsey formation.

EXPLANATION OF PLATE IX

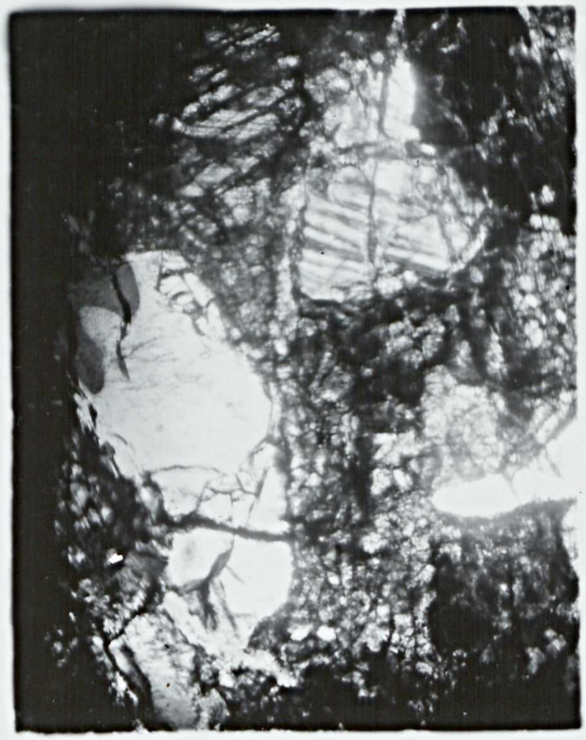
A: Photomicrograph of thin section of green Belt arkose showing hornblend crystals partly replaced by chlorite.

B: Photomicrograph of thin-section of Red Belt arkose showing grain of microcline-microperthite (note twinning) and iron stained feldspar.

C: Photomicrograph of thin-section of Cambrian arkose showing grain of microcline-microperthite and iron stained feldspar.

PLATE 9
Photomicrograph of Arkose near Limespur (x55)

(A) Belt arkose (crossed nicols)



(B) Belt arkose (crossed nicols)

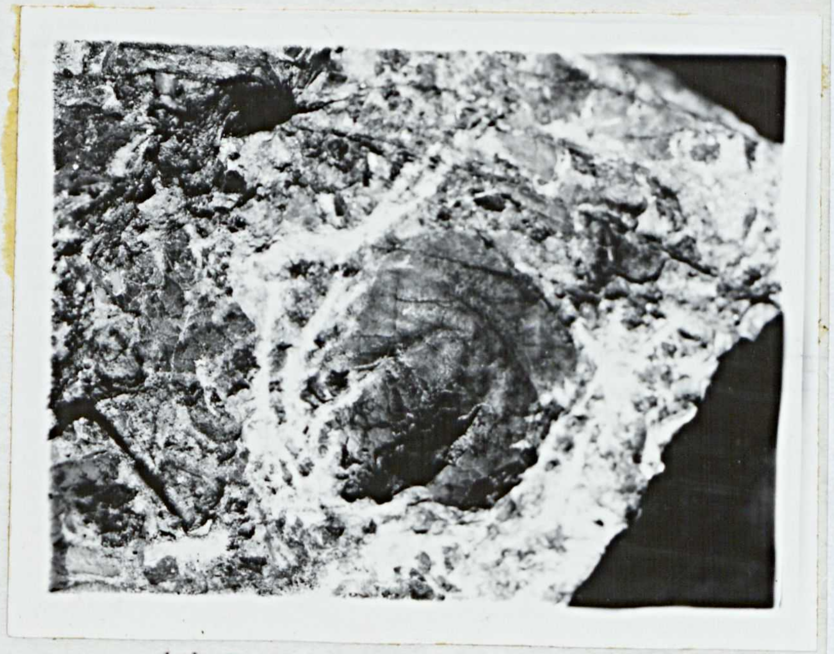
(C) Cambrian Arkose

PLATE 10

Photographs of Trilobites Found near Limespur

(A)Neolenus

(B) Kootenai



(C) Idahoia