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ORGANIC PETROGRAPHIC AND ROCK-EVAL PYROLYSIS ANALYSES OF PROTEROZOIC BELT SUPERGROUP ROCKS, WEST CENTRAL MONTANA

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INTRODUCTION

The prime purpose of this study was to analyze through organic petrographic and pyrolysis techniques, a reconnaissance suite of samples of Proterozoic rocks in west-central Montana in order to contribute to the assessment of the petroleum resources of the region by obtaining information on overall organic content and thermal maturity with respect to hydrocarbon generation. A secondary purpose was to add new information to a continuing project on the character of organic matter and petroleum potential of Precambrian rocks (Reynolds and others, 1988; Palacas and Reynolds, 1989; Pawlewicz and Palacas, 1992.

The Proterozoic of central and western Montana is comprised of a thick set of rocks collectively known as the Belt Supergroup. The lithologies represented in this great thickness (up to 13,000 feet (3,960 m), Zieg and Godlewski,1986) are argillaceous and calcareous shale, quartzite, sandstone and limestone. The Belt Supergroup has been studied in great detail since before the turn of the 20th century.Detailed descriptions and summaries of the development of the formational names and relations are given in Winston, 1986. In addition, Winston and others, (1984) gives a good statigraphic and sedimentological overview of the Belt Basin. It is the tantalizing sedimentology and facies variations within formations, due to the regional extent of the formations, immense thickness, and the very complex structural nature of the Supergroup as a whole that has made these rocks of great interest and contention to the present day. In addition, the search for hydrocarbons- oil and gas, has imparted, perhaps, even a greater interest extending down to the very chemistry of individual formations.

LOCATION MAP

The study area is located in central and west-central Montana, in the region between Helena, Townsend, White Sulfur Springs and Neihart (Fig. 1). The location of each sample is shown by a solid circle in Figure 1. Table 1 provides specific latitudes and longitudes, as well as section, township and range.

SAMPLE COLLECTION AND DESCRIPTION OF FORMATIONS SAMPLED

Thirty-six samples were originally collected for this study according to their lithology. Only unweathered samples were selected; that is the rock material was taken from beneath the surface of the outcrop, to ensure a fresh, unoxidized sample. Darker colored rocks were selected first, where available. This was done to increase the likelihood of finding anything that might be organic. Locations were determined from the road logs of Zieg and Godlewski (1986), and from Winston and Woods (1986). After screening by visual and Rock-eval analyses, the suite was reduced to the present number of 21.

The Newland Formation is most prevalent across the study area and was the most frequently sampled because of its lithology and darker color, which often indicates a higher probability of being a hydrocarbon source rock. In addition, samples were taken from the Chamberlain and Greyson Shales, and the Empire and Helena Formations. Figure 2, from Earhart and others, (1984), is a generalized stratigraphic section from the study area.

The following rock descriptions and thicknesses are generally from Zieg and Godlewski (1986) for rock outcroppings along a road log traverse that also aided in the sample collection. The descriptions are not meant to depict all lithologic variations.

The Chamberlain Shale is the oldest unit sampled. It is somewhat friable, dark gray to black, and fissile, containing numerous lenticular quartz interbeds. In addition, it also contains carbonate beds up to 3 feet thick, with dark gray and black shale interlayers. The thickness of this unit is estimated at greater than 3,100 feet (945 meters) in the region between Neihart and White Sulfur Springs, and Townsend.

The Newland Limestone is complex with a wide variety of lithologies, and sedimentary features. It can be a silty carbonate or a silty shale with limestone or chert nodules. Also, cross-laminated silty layers and dark gray shale interbeds, along with sandy lenses occur in the lower Newland. Zieg (1986) provides a very detailed description of the upper and lower Newland Limestone. The estimated thickness is greater than 5,000 feet (1,500 meters) in the same area as the Chamberlain Shale.

The Greyson Shale is a silty shale, non-calcareous, and generally dark gray, with quartzite occurring in places, particularly at the base. Its reported thickness is greater than 3,000 feet (950 meters).

According to Mertie and others (1951) the Empire Shale has a maximum thickness of about 1,000 feet (330 m). It is commonly a hard, dense thinly bedded, siliceous shale or argillite. The color ranges from light to dark shades of greenish gray. There are some thin beds of limestone interlayered in the upper part of the formation.

Winston and Woods (1986), report that the Helena Formation is characterized by rocks suggesting deposition of terrigenous-to-carbonate cycles. There is alteration of thin, dark argillite with resistant blocky, tan-weathering dolomite. Concentrations of stromatolites and molar-tooth structures vary by stratigraphic locality; they are rare in the lower cycles and more common higher up in the section. In addition, there is coarse quartz and oolitic sandstones. Earhart and others (1984) put the thickness between 175 and 2,865 meters (525 and 8,100 feet) from the Swan Range far to the northwest of the study area.

SAMPLE ANALYSIS

Twenty-one samples were collected from five formations and analyzed for organic matter by Rock-Eval pyrolysis and with reflected light microscopy. The samples were prepared for microscopy analysis by crushing into 1-3 mm size pieces and casting in epoxy resin. Preserving the stratigraphic integrity in a whole rock preparation would keep intact any organic matter (OM) and rock matrix relationship. This is because there are Proterozoic entities, (probably chitinous remains of marine creatures - organic but with a different responce to thermal maturation than terrigenous organic material) though not necessarily organic matter, found throughout the world, many of which have not been identified (Murray, and others, 1980). A heavy liquid concentration of OM was not performed, in part because Rock-Eval analysis indicated only low concentrations of organic matter.

The reflected light technique was used to observe any "organic matter" and characterize its origin in terms of type and source. Rock-Eval pyrolysis is a bulk rock technique used to measure the quantity, quality and level of thermal maturity of hydrocarbons released by heating. These types of data give some indication of the hydrocarbon potential of these possible source rocks. See Table 1 for the geochemical results.

RESULTS

Organic Petrographic Analysis

The whole-rock samples were scanned in reflected white light to locate "organic or vitrinite-like" material for reflectance measurements, and to describe such material that may be present for the purpose of identifying a source of any type of organic material. Incident light analysis of the twentyone samples was inconclusive. The following samples contained material that could be interpreted as type III kerogen, or of terrigenous origin: nos. 3, 4, 8, 9, 10, 16, 17 from the Newland Limestone; nos. 2 and 11 from the Grayson Formation; nos. 13 and 14 from the Chamberlain Shale; and no. 12 from the Empire Formation. However, land plants did not exist in the Proterozoic when these rocks were deposited. The material within the samples is probably from algae.

The general lack of OM in these samples precluded gathering any appreciable number of reflectance measurements for extrapolation or comparison with the Rock-Eval analyses. The very small size of the particles, up to 40 microns long but only about 1 to 3 microns wide, made any identification of the material nearly impossible.

The most common and distinguishing constituents with any resemblance to "organic matter" were micro-fine pieces of bright white material, typically about 2 X 3 microns in size. These particles were too small to obtain reflectance measurements. They had the look of material which was emplaced at the time of deposition and then compressed by continued sedimentation. Again, insufficient size and surface area prevented obtaining more than a rudimentary description.

A second habit of the bright particulate material was as incomplete rims around voids which may be actual holes or crosssections of pellets or clay floccules. The voids were not created by plucking of material during polishing. One feature of these rims which indicated a former, more mobile state, was an occurrence of cubic and triangular holes in a larger piece of the anomalous material. These shapes would result from pyrite crystals removed during preparation. Pyrite, in the form of small euhedral crystals or massive, irregular shapes, was common in the samples, varying from about 1 to 3 percent by volume with all 21 samples.

In general, this bright white "vitrinite-like" material occurred within some kind of depositional feature such as dark streaks parallel to bedding or the above mentioned rims around pellets or floccules. However, in three cases the particulate matter appeared in the middle of the rock sample without any relationship to a sedimentary feature. That the dark laminae coincide with bedding suggest this material was either flora or fauna that was deposited intermittantly. An alternative explanation is that the material, possibly bitumen, was generated and migrated into position in the rock laminae prior to induration. This unidentified material does resemble Paleozoic type III organic material. The following discussion of the Rock-Eval analyses demonstrates how little organic material there is in the Belt rocks despite attempts to procure darker colored, and thus more "organic"-rich, rocks from the Supergroup.

Rock-Eval Analyses

The Rock-Eval pyrolysis yields several parameters; the results are listed in Table 1. S_1 is a measure of free hydrocarbon (HC) already in the rock; S_2 is a measure of HC generated by pyrolysis, and S_3, a measure of carbon dioxide. Total organic carbon (TOC), S1, S2, and S3 are exceedingly low here indicating that these Precambrian rocks are very poor source rocks for generating commercial amounts of petroleum.

The TOC values are less than the generally accepted threshold for any hydrocarbon generation, about 2.0 percent (Tissot and Welte, 1984). The Hydrogen Indices (HI) values are too low for hydrocarbon generation.

The level of thermal maturation for these samples is obscured by the poor and somewhat random nature of the analytical results. The Tmax data suggest that these rocks are thermally overmature.

SUMMARY AND CONCLUSIONS

Interpretations from this syudy are limited by the relatively small amount of data and the large area it represents. One objective was met, though, the determination of the general 'organic' content of the Belt rocks in this area. The data show that there is minimal organic matter in these rocks a fact made clear by both the visual and the Rock-Eval analyses. This fact addresses the hydrocarbon assessment of the area, and strongly suggests that there is no hydrocarbon potential in the surface Belt rocks in the region sampled. However, this does not preclude the subsurface rocks, both Proterozoic and younger rocks covered by thrust sheets, where generation and entrapment may have occurred.

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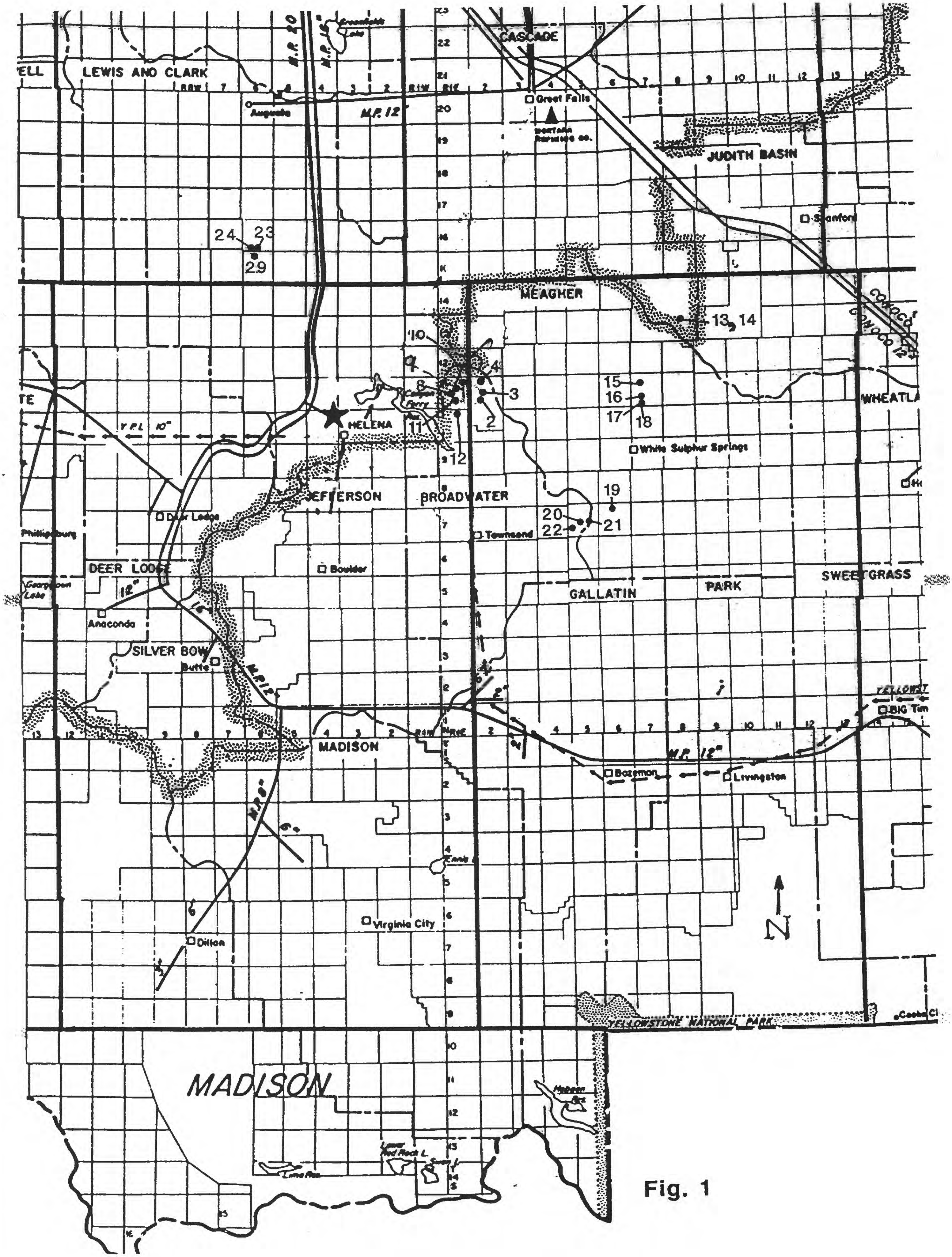
FIGURE CAPTIONS

Figure 1. Map of west-central Montana showing sample locations. From Montana Oil and Gas 1992 Annual Review, V. 36, 58 pp.

Figure 2. Generalized stratigraphic column/correlation chart of Belt Supergroup rocks in western Montana. From Earhart and others, 1984.

Table 1. Results of Rock-Eval analyses.

Rock-Eval is a standard pyrolysis (heating) method of source rock characterization and evaluation whereby samples of pulverized rock are progressively heated to 550°C under an inert atmosphere, using a special temperature program. During this programmed heating, the hydrocarbons already present in the rock are volatilized- this is the S_1 parameter. S_2 represents the hydrocarbons or hydrocarbon-like compounds generated from any kerogen in the sample; S_3 represents any oxygen-containing volatiles such as carbon dioxide. T_{max} is the temperature at which maximum generation of hydrocarbons takes place during the pyrolysis. TOC is total organic carbon, the measure of organic carbon in milligrams per gram. HI or hydrogen index is S2/organic carbon and OI or oxygen index is S3/organic carbon. Both indices are characterizing the type of kerogen, they are strongly related to elemental composition of the kerogen.



LEWIS AND CLARK
CASCADE
Great Falls
Augusta
JUDITH BASIN
Stanford
MEAGHER
WHEATLAND
HELENA
White Sulphur Springs
JEFFERSON
BROADWATER
Deer Lodge
Townsend
Boulder
DEER LODGE
GALLATIN
PARK
SWEETGRASS
Anaconda
SILVER BOW
Butte
MADISON
Bozeman
Livingston
Big Timber
Ennis
Virginia City
Dillon
YELLOWSTONE NATIONAL PARK
MADISON
Canyon Ferry
Phillipsburg
Georgetown Lake
M.P. 12"
Y.P.L. 10"
CONOCO 12"
N

Fig. 1

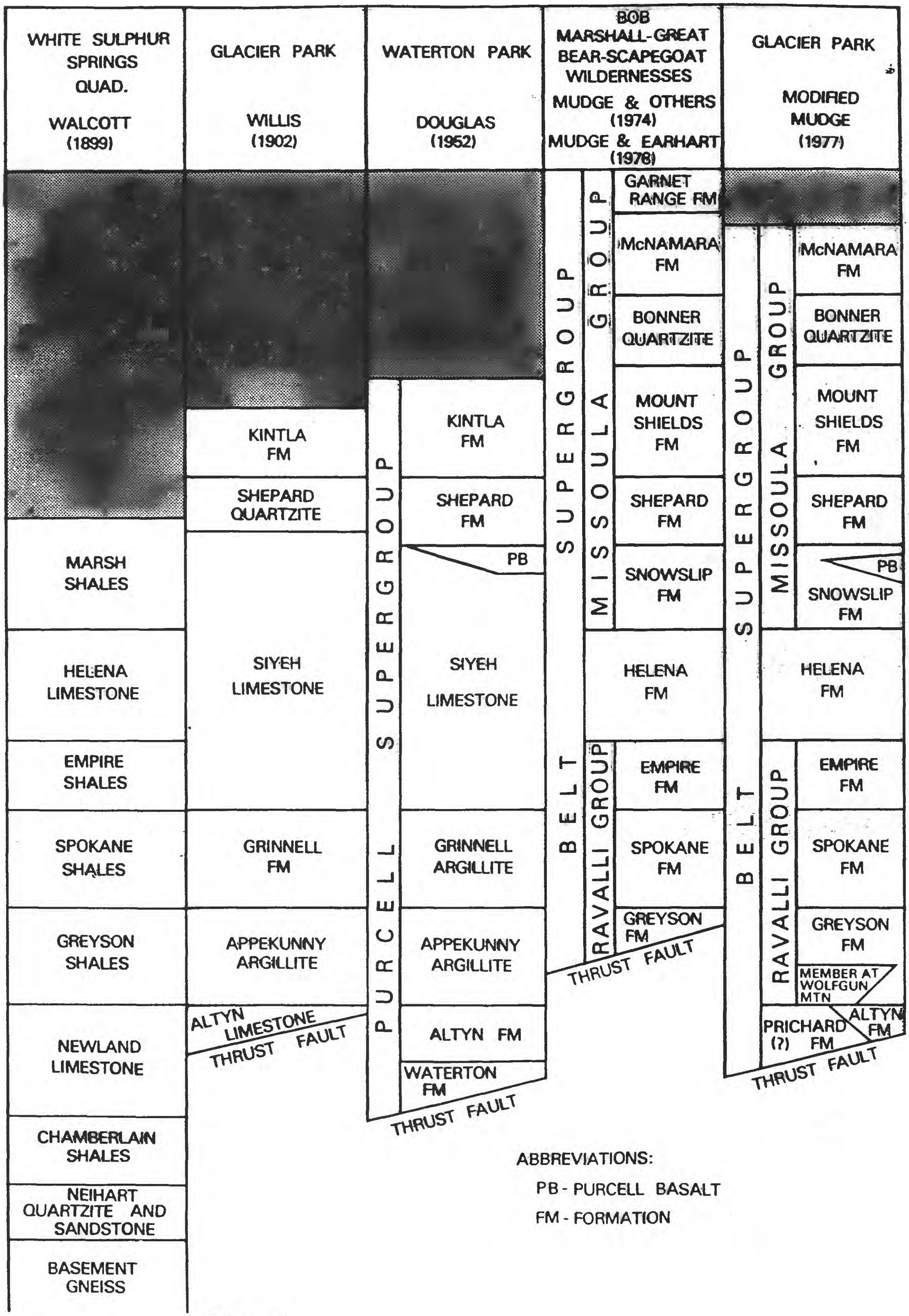

WHITE SULPHUR SPRINGS QUAD.
WALCOTT (1899)
GLACIER PARK
WILLIS (1902)
WATERTON PARK
DOUGLAS (1952)
BOB MARSHALL-GREAT BEAR-SCAPEGOAT WILDERNESSES
MUDGE & OTHERS (1974)
MUDGE & EARHART (1978)
GLACIER PARK
MODIFIED MUDGE (1977)
MARSH SHALES
HELENA LIMESTONE
EMPIRE SHALES
SPOKANE SHALES
GREYSON SHALES
NEWLAND LIMESTONE
CHAMBERLAIN SHALES
NEIHART QUARTZITE AND SANDSTONE
BASEMENT GNEISS
KINTLA FM
SHEPARD QUARTZITE
SIYEH LIMESTONE
GRINNELL FM
APPEKUNNY ARGILLITE
ALTYN LIMESTONE
THRUST FAULT
PURCELL SUPERGROUP
KINTLA FM
SHEPARD FM
PB
SIYEH LIMESTONE
GRINNELL ARGILLITE
APPEKUNNY ARGILLITE
ALTYN FM
WATERTON FM
THRUST FAULT
BELT SUPERGROUP
MISSOULA GROUP
GARNET RANGE FM
McNAMARA FM
BONNER QUARTZITE
MOUNT SHIELDS FM
SHEPARD FM
SNOWSLIP FM
HELENA FM
RAVALLI GROUP
EMPIRE FM
SPOKANE FM
GREYSON FM
THRUST FAULT
BELT SUPERGROUP
MISSOULA GROUP
McNAMARA FM
BONNER QUARTZITE
MOUNT SHIELDS FM
SHEPARD FM
PB
SNOWSLIP FM
HELENA FM
RAVALLI GROUP
EMPIRE FM
SPOKANE FM
GREYSON FM
MEMBER AT WOLFGUN MTN
PRICHARD (?) FM
ALTYN FM
THRUST FAULT
ABBREVIATIONS:
PB - PURCELL BASALT
FM - FORMATION

Fig. 2

Table 1

Sample#	Formation	Location	Location	County	Tmax	S1	S2	S3	TOC	HI	OI
		Sec.,Tshp.,Rng	Lat/Lon		°C						
MPPC-1	Empire	1, 11N., 1E.	46.657::111.557	Broadwater	602	0	0.18	0.06	0.02	900	300
MPPC-2	Greyson	30, 11N., 2E.	46.681::111.525	Broadwater	540	0.02	0.32	0.09	0.16	200	56
MPPC-3	Newland	20, 11N., 2E.	46.700::111.500	Broadwater	528	0.01	0.16	0.18	0.11	145	163
MPPC-4	Newland	5, 11N., 2E.	46.742::111.513	Broadwater	541	0	0.05	0.17	0.11	45	154
MPPC-8	Newland	16, 11N., 1E.	46.701::111.613	Broadwater	473	0	0.08	0.56	0.18	44	311
MPPC-9	Newland	9, 11N., 1E.	46.725::111.608	Broadwater	526	0	0.07	0.31	0.14	50	221
MPPC-10	Newland	9, 11N., 1E.	46.729::111.600	Broadwater	448	0	0.07	0.77	0.06	116	1283
MPPC-11	Greyson	29, 11N., 1E.	46.688::111.642	Broadwater	599	0.01	0.32	0.27	0.05	640	540
MPPC-12	Empire	3, 10N., 1E.	46.650::111.725	Lewis and Clark	428	0.01	0.1	0.55	0.01	1000	5500
MPPC-13	Chamberlain	10, 13N., 8E.	46.913::110.700	Cascade	545	0	0.3	0.12	0.33	90	36
MPPC-14	Chamberlain	10, 13N., 8E.	46.879::110.708	Cascade	530	0	0.08	0.13	0.15	53	86
MPPC-15	Newland	8, 11N., 7E.	46.747::110.910	Meagher	505	0	0.04	0.68	0.18	22	377
MPPC-16	Newland	29, 11N., 7E.	46.694::110.922	Meagher	343	0	0	0.31	0.63	0	49
MPPC-17	Newland	32, 11N., 7E.	46.675::110.923	Meagher	500	0	0.22	1.04	0.18	122	577
MPPC-18	Greyson	32, 11N., 7E.	46.663::110.925	Meagher	514	0	0.05	0.1	0.03	166	333
MPPC-19	Greyson	4, 7N., 6E.	46.415::110.975	Meagher	584	0	0.04	0.07	0	0	0
MPPC-20	Greyson	23, 7N., 5E.	46.358::111.075	Broadwater	590	0	0.05	0.03	0	0	0
MPPC-21	Greyson	21, 7N., 5E.	46.363::111.106	Broadwater	474	0	0.02	0.18	0.18	11	100
MPPC-22	Newland	30, 7N., 5E.	46.342::111.163	Broadwater	484	0	0.07	0.12	0.18	38	66
MPPC-23	Greyson	34, 16N., 6W.	47.100::112.354	Lewis and Clark	519	0	0.09	0.19	0.04	225	475
MPPC-29	Helena	4, 15N., 6W.	46.942::112.800	Powell	540	0	0.07	0.18	0.12	58	150