

**DIGITAL STRUCTURE MAP OF THE PRECAMBRIAN SURFACE,
CENTRAL AND EASTERN MONTANA**

Jay A. Gunderson

Montana Bureau of Mines and Geology

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INTRODUCTION

Archean and Early Proterozoic igneous and metamorphic rocks are exposed in several mountain ranges of southwestern Montana and in the cores of some Laramide-age uplifts east of the Rocky Mountain Fold and Thrust Belt (fig. 1). Middle Proterozoic sedimentary rocks of the Belt Supergroup are exposed in much of western and northwestern Montana. For the remainder of the plains of central and eastern Montana, Precambrian rocks are buried beneath up to 15,000 ft of Phanerozoic sedimentary rocks.

The contact between Precambrian and Phanerozoic rocks in the subsurface represents an important geologic horizon for several reasons: (1) it commonly marks the boundary between igneous and metamorphic “basement” rocks and overlying layered sedimentary rocks (i.e., it forms the base of Phanerozoic basin fill); (2) it represents a major unconformity with ~600–2,000 m.y. of missing rock record; and (3) it is generally the lowermost recognizable and mappable surface in the Earth’s upper crust. It is also considered one of the key surfaces for constructing a continental-scale digital 3D geologic model under the U.S. Geological Survey’s GeoFramework Initiative.

Moss (1936) identified the major structural features of the buried Precambrian surface for most of the continental U.S. during a study of their genetic relationships. Several decades later, members of the American Association of Petroleum Geologists formed the Basement Rock Project Committee to develop a continental-scale map showing the topography of the Precambrian surface (American Association of Petroleum Geologists, 1967; Flawn, 1968). This was a springboard for further work by the U.S. Geological Survey (Bayley and Mehlberger, 1968). Bergantino and Clark (1985) published the most recent Precambrian structure contour map for Montana’s plains, east of the Rocky Mountain Fold and Thrust Belt. Their map was used in Domrois’s (2013) compilation for the U.S. cratonic platform and subsequently published as a digital elevation model (Domrois and others, 2015; Marshak and others, 2017). It remains true, however, that the most recent interpretation of the Precambrian surface in central and eastern Montana was done nearly 40 years ago.

Evaluating the quality of earlier interpretations can be challenging because many authors omit the data and methods they used in their interpretations. Thus, the goals of this study are: (1) compile a current dataset of drill holes that have penetrated the Precambrian surface; and (2) create an updated digital structure map of the buried Precambrian surface for central and eastern Montana. The primary digital product is an ESRI ArcPro geodatabase containing elevations of the Precambrian surface from well data, an elevation grid and raster surface covering the eastern two-thirds of Montana, and a set of structure contour lines generated from the elevation grid. The well data are included so they can be easily used, modified, and augmented as new well data become available or as geoscientists reinterpret existing well data.

DATA AND METHODS

One hundred seven (107) petroleum exploration wells drilled in Montana were determined to have reached Precambrian rocks (table 1); 88 are located within the study area of central and eastern Montana. These “Precambrian wells” were identified from:

1. Published reports listing specific wells drilled to the Precambrian surface, along with the depths/elevations where that surface was intersected (Vine and Erdmann, 1952; Smith, 1955; Sims and others, 1991).
2. Well operators’ formation tops, available from the Montana Board of Oil and Gas (MBOG; <https://bogapps.dnrc.mt.gov/dataminer/Default.aspx>).
3. Northwest Geological Society (NWGS) lithology logs, available from the Montana Geological Society (<https://mtgeo.org/resources/nwgs-projects/>).
4. Published reports that list Precambrian wells, but without any associated depth/elevation information (Tullis, 1952; Garcia-Ramirez and Helland, 1985; Nelson, 1992).

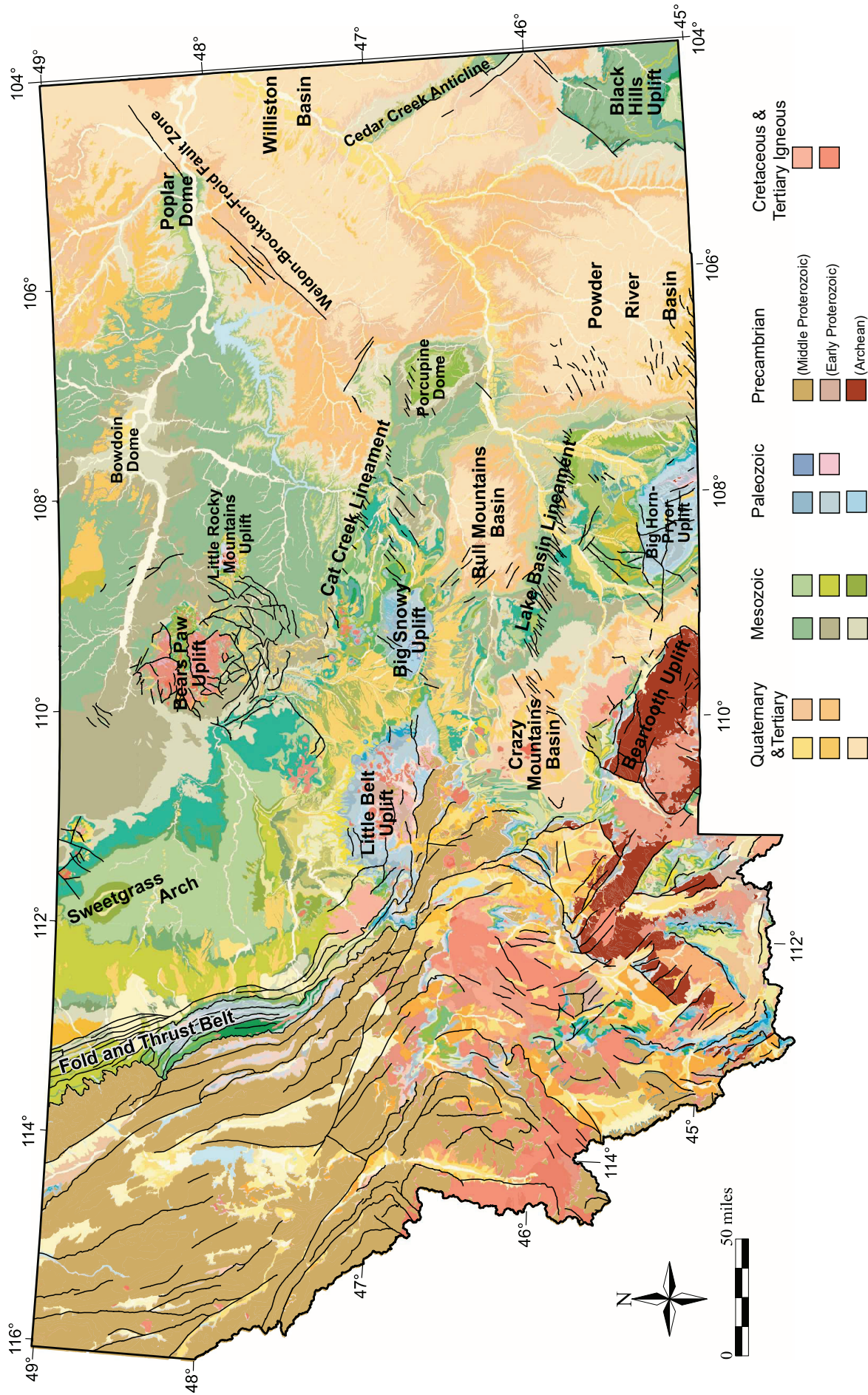


Figure 1. General geologic map showing the major tectonic features of central and eastern Montana (modified from Vuke and others, 2007). The surface traces of faults are shown as black lines.

Each well was reviewed and verified as having reached Precambrian rocks using a combination of lithologic descriptions from well files, mudlogs, NWGS logs, geophysical logs, and on occasion, inspection of drill cuttings available at the MBOG. Well header and location data were acquired from the MBOG. Geophysical logs and mudlogs were obtained from MJ Systems of Calgary, Alberta. NWGS logs were acquired from the Montana Geological Society (<https://mtgeo.org/resources/nwgs-projects/>). All well header data and geophysical logs were loaded into S&P Global's (formerly IHS) PETRA software for analysis.

Because only 88 wells penetrate the Precambrian surface in the study area—too few to accurately depict the topography of the Precambrian surface on their own—we estimated the Precambrian elevation for another 222 wells by projecting downward from shallower horizons. Precambrian elevations for 8 wells were estimated by projecting downward from the top of the lowermost Cambrian Flathead Formation (Fm). The thickness of the Flathead Fm averages approximately 120–125 ft (Lindsey, 1980), particularly in central Montana where 7 of the 8 wells are located. Flathead Fm thicknesses were adjusted where nearby well control was available. Because the projected elevations of the Precambrian surface at these 8 well locations is likely to be within ± 50 ft of actual elevations, they are included in table 1. For another 214 wells, elevations of the Precambrian surface were estimated by projecting downward from the top of Cambrian strata using a Cambrian isopach map developed as part of this study.

Precambrian elevation data used for gridding and contouring are, in order of reliability: (1) actual elevations taken from well data and Precambrian exposures in the Big Snowy, Little Rocky, Pryor, Bighorn, and Little Belt Mountains (fig. 1); (2) fairly reliable estimates of Precambrian elevation for 8 wells that reached the lowermost Cambrian Flathead Fm; (3) reasonable estimates of Precambrian elevation projected downward from the top of Cambrian strata using a Cambrian isopach map developed from well and outcrop data; (4) existing structure contours from Bergantino and Clark (1985), particularly for the area south of the Lake Basin Lineament and west of the Powder River Basin (fig. 1); and (5) approximate elevations derived from published and unpublished cross-sections and structure maps drawn on shallower horizons (e.g., Dobbin and Erdmann, 1955; Bergantino, 1985).

Well data and Precambrian elevation contours from adjacent states and provinces were included to improve “edge-matching” along the borders between Montana and North Dakota (Heck, 1988; Anderson, 2009), South Dakota (McCormick, 2010), Wyoming (Blackstone, 1993a, b), Alberta (Alberta Geological Survey, 2023), and Saskatchewan (Government of Saskatchewan, 2023).

Elevation data were loaded into the PETRA software and gridded using a 2,000-m-square grid spacing and PETRA's “Least Squares Method” interpolation algorithm. We used a “stepwise approach” to gridding, whereby the most reliable data (i.e., actual elevations from well data) were used to generate an initial elevation grid and surface. During subsequent grid iterations, we added data of lesser reliability (i.e., elevations projected downward from shallower strata) to fill in gaps where data were sparse, but used the contour lines generated in prior grid iterations to guide the gridding, and thus continued to rely most heavily on measured Precambrian elevation data.

The final, edited XYZ grid from PETRA was imported into ArcPro and converted to an ESRI raster using a 500 m cell size. The set of contour lines generated in PETRA were imported directly into ArcPro. The raster surface and contour lines were “clipped” to the Montana state boundary and, to the west, to a line roughly coincident with Precambrian surface exposures. Well data and results are shown in plate 1.

RESULTS

The data and results from this project are contained in an ESRI ArcPro geodatabase (MT_Precambrian_Structure.gdb) and illustrated in plate 1. The coordinate reference system for the elements contained in the geodatabase is NAD83 State Plane Montana FIPS 2500 (m). A map package (MT_Precambrian_structure.mpkx) is also provided to preserve the symbology used in plate 1.

Table 1. Wells that penetrate the Precambrian (PC) surface in Montana.

COMPLETION												
API	OPERATOR	WELLNAME	COMPLETION DATE	COUNTY	TWP	RNG	SEC	ELEV KB (ft)	DEPTH PC (ft)	ELEV PC (ft)	Geo Unit	Ref*
25001210050000	American Quasar Petroleum	Rebush 29-1	4/30/1978	Beaverhead	5S	7W	29	4859	6138	-1279	X	
25001210080000	Amoco Production Company	J. Hirschy Livestock 1	8/22/1981	Beaverhead	3S	16W	27	6415	15910	-9495	B	
25001210100000	Amoco Production Company	J. Hirschy Livestock 2	4/23/1983	Beaverhead	4S	15W	31	6399	9341	-2942	B	
25003050740000	Soap Creek Associates, Inc.	Crow Tribal 52-34	8/19/1948	Big Horn	6S	32E	34	3613	4442	-829	X	2.6
25003210960000	Shadco	Reed 2	8/20/1975	Big Horn	6S	32E	28	3592	4677	-1085	X	
25003211630000	RME Petroleum Company	Kendrick 1 13-15	2/1/1983	Big Horn	2N	35E	15	3186	9179	-5993	X	
25003211700000	RME Petroleum Company	Kendrick #2 21-7	1/14/1984	Big Horn	1N	36E	7	3471	9413	-5942	X	
25005050020000	Phillips Petroleum Company	FT BELKNAP 1-A	5/10/1956	Blaine	28N	23E	3	2916	7066	-4150	X	6
25007050030000	Capital Energy	Capitol Oil & Gas Co. 1	7/10/1936	Broadwater	8N	1E	7	4368	2000	2368	B	
25007210010000	Harper Oil Company	Federal 2-24	4/5/1981	Broadwater	6N	1E	24	4484	0	4484	B	
25009210320000	Black Butte Oil	Fleegal 1	7/1/1973	Carbon	7S	24E	35	5226	2230	2996	X	
25009212010000	Amoco Production Company	USA AMOCO A 1	4/3/1988	Carbon	8S	20E	19	6279	0	6247	X	
25011050040000	Union Oil Company of CA	FEDERAL 1	9/10/1956	Carter	9S	58E	29	3557	4840	-1283	X	7
25011050050000	Union Oil Company of CA	FEDERAL 1	10/1/1956	Carter	9S	59E	23	3444	4859	-1415	X	6,7
25011050440000	Union Oil Company of CA	GOVERNMENT 1	9/8/1955	Carter	8S	56E	1	3636	6331	-2695	X	6,7
25011050560000	Skelly Oil	GOV'T-BERGEN 1	9/20/1956	Carter	7S	56E	14	3841	7079	-3238	X	6,7
25011050640000	Union Oil Company of CA	Government Hamilton 1	10/18/1955	Carter	6S	57E	21	3708	7210	-3502	X	7
25011050650000	Union Oil Company of CA	Government 09709 2	12/15/1955	Carter	6S	58E	17	3684	7118	-3434	X	7
25011050910000	Carter Oil Co.	Traweeek 1	9/21/1953	Carter	2N	61E	6	3170	10358	-7188	CF	
25011212790000	Marathon Oil Company	State 1	1/24/1979	Carter	2N	61E	16	3147	10242	-7095	X	6,7
25011213230000	Axem Resources Incorporated	Hackberry Creek 13-1	1/24/1984	Carter	5S	60E	1	3404	8255	-4851	X	7
25013210290000	Cascade Gas Co.	ANDERSON<-14-15	6/17/1981	Cascade	20N	2E	15	3577	3750	-173	B	
25013210430000	Nyvatec Montana Corp.	26-1XD FRIEDMAN	5/8/1986	Cascade	20N	2E	26	3663	3718	-55	B	
25013210470000	Halvar Resources, Inc.	16-22 HALKOA	8/12/1986	Cascade	19N	4E	22	3810	3690	120	B	
25013210480000	Nyvatec Montana Corp.	24-1 RSGL PTNSP	9/21/1986	Cascade	20N	2E	24	3639	3666	-27	B	
25015050460000	General Petroleum	KAUN 8-11-P	1/1/1951	Chouteau	27N	3E	11	3287	4191	-904	X	2
25015211280000	Cascade Gas Co.	HIGGINS 1	7/18/1972	Chouteau	27N	6E	30	3351	5593	-2242	B	6
25015214930000	Conoco Inc.	LIPPETT 1-17	12/23/1978	Chouteau	26N	7E	17	3265	5450	-2185	6	
25015215270000	Shadco	GEMAR 1-5	12/23/1980	Chouteau	25N	3E	5	3340	4818	-1478	B	
25015216290000	S & J Operating Co	MAUER 1	8/24/1986	Chouteau	25N	3E	5	3331	4891	-1560	B	
25017010000000	USGS	Madison 2	1/1/1978	Custer	1N	54E	18	2809	9300	-6491	X	6,7
25017050180000	Pure Oil	STATE 1	9/1/1946	Custer	2N	51E	36	3017	9985	-6968	X	1,2,7
25019211020000	Nerdilhc Company Inc.	Fugere 7-30	4/20/1994	Daniels	34N	48E	30	2658	10610	-7952	X	
25019211270000	HS Resources, Inc.	Hersel 14-5	4/29/1995	Daniels	35N	45E	5	2986	10221	-7235	X	
25021050840000	Cortez Operating Company	NPRR (NCT-11) 1	12/28/1951	Dawson	15N	54E	35	2338	10282	-7944	X	
25025050200000	Carter Oil Co.	NPRR 1	10/3/1941	Fallon	4N	62E	19	3065	9654	-6589	X	1,2,6,7
25025055430000	Denbury Onshore, LLC	Unit 21-17	3/27/1958	Fallon	10N	58E	17	2743	10493	-7750	X	6,7
25025211350000	Marathon Oil Company	BN COASTAL 1	11/27/1978	Fallon	5N	58E	13	3368	11131	-7763	X	6,7
25027050560000	United Petroleum & Mining	WOODWORTH 1	7/17/1953	Fergus	14N	24E	20	4316	3890	426	B	8
25027212070000	Black Eagle Operating Co.	DELANEY 1-35	8/20/1985	Fergus	17N	23E	35	3391	5687	-2296	B	8
25029210050000	Cenex, Inc.	Ladenburg 4-13	10/31/1989	Flathead	34N	21W	13	3482	3064	418	B	
25031210030000	Phillips Petroleum Company	BRAINARD B 1	5/18/1985	Gallatin	4N	4E	26	5414	11435	-6021	B	
25033051080000	General Petroleum	NPRR 5-25	1/30/1949	Garfield	16N	38E	25	3186	8997	-5811	X	1,2,8
25033210690000	Amoco Production Company	AMOCO BN-D 1	8/4/1980	Garfield	16N	43E	11	2548	10633	-8085	X	
25033210710000	Atlantic Richfield Company	SALZGEBER 1-32	7/22/1981	Garfield	15N	35E	32	3446	9555	-6109	X	6,8
25033210720000	Atlantic Richfield Company	COASTAL B<-1-33	7/13/1981	Garfield	15N	35E	33	3315	9511	-6196	X	8
25033600100000	Brown, Joe W.	Binion Ranch 1	12/22/1957	Garfield	20N	39E	21	2716	9073	-6357	CF	
25035221440000	Ovintiv USA Inc.	Old West 1-9-16H	7/19/2011	Glacier	33N	7W	9	4002	7550	-3548	B	
25039210040000	Energy Operating Corporation	Henderson 1	4/4/1978	Granite	10N	13W	9	4505	0	4505	B	
25039210070000	Trans-Texas Energy, Inc.	Henderson-Lorensen 2	10/28/1982	Granite	11N	13W	33	4692	16870	-12178	B	
25041050770000	Texaco Expl and Prod Inc.	R. E. BAIR 1	7/6/1960	Hill	34N	9E	28	3065	6243	-3178	X	6
25041221410000	Salmon Resources	CONWAY 1	10/6/1980	Hill	34N	11E	20	2930	6857	-3927	X	

Table 1—Continued.

API	OPERATOR	WELLNAME	COMPLETION DATE	COUNTY	TWP	RNG	SEC	ELEV KB (ft)	DEPTH PC (ft)	ELEV PC (ft)	Geo Unit	Ref*
25043210020000	Norcen Explorer Inc.	Kimpton 1-11	4/1/1991	Jefferson	4N	2W	11	5396	2220	3176	B	
25045050020000	Doswell, T.W.	DOLGAN 1	8/19/1950	Judith Basin	11N	15E	12	4800	4956	-156	CF	6
25049210130000	Union Oil Company of CA	Federal 1-B30	11/27/1989	Lewis and Clark	14N	5W	30	6833	0	6833	B	
25049211080000	Suncor Energy America Inc.	Sieben Ranch 14603-12	8/4/2005	Lewis and Clark	14N	6W	3	5626	0	5626	B	
25051218350000	Thor Resources USA, LLC	Laas 22-14	2/2/2022	Liberty	33N	4E	14	3404	5811	-2407		
25051218430000	Avanti Helium US, Inc.	Western Natural gas	11-22 4/9/2022	Liberty	34N	4E	22	3933	5237	-1304	X	
25055050190000	Shell Oil Company	NPRR 32-33B	7/19/1953	McCone	22N	48E	33	2499	11000	-8501	X	3,6,7
25057050010000	Poynter, Sam	Code Estate 1	9/14/1939	Madison	7S	1W	17	5280	0	5280	X	
25057210040000	Helis, Estate of William G.	Conley Ranch 1-27	5/11/1984	Madison	8S	5W	27	5712	2540	3172	X	
25057210060000	North American Res. Co.	State 3-8	7/31/1982	Madison	4S	5W	8	5045	2160	2885	X	
25057210070000	Helis, Estate of William G.	BOOMHAUER 1-27	7/8/1984	Madison	8S	1E	27	5918	-7	-7	X	
25057210080000	Texaco Oils Inc., A DE Corp.	JS GRANGER A 1	12/21/1984	Madison	7S	1E	18	5512	7524	-2012	X	
25065050540000	Oxy Petroleum Inc	NP 2	5/18/1964	Musselshell	9N	23E	17	3723	7473	-3750	CF	
25065052670000	Richfield Oil	NP 1-A	5/21/1959	Musselshell	10N	25E	5	3756	5503	-1747	B	6,8
25065054060000	RME Petroleum Company	NPRR 1-13	8/9/1958	Musselshell	11N	27E	13	3364	6950	-3586	CF	
25065210530000	Texaco Expl and Prod Inc.	A.S. ZOERB 5	3/25/1969	Musselshell	10N	27E	18	3265	5500	-2235	B	6,8
25065211890000	Marathon Oil Company	BN 1	8/30/1973	Musselshell	11N	24E	9	3939	4830	-891	X	6,8
25065218360000	FX Drilling Company, Inc.	Murray 12-30	9/4/1997	Musselshell	11N	25E	30	3783	4933	-1150	B	
25069210870000	Marmik Oil Company	MLEKUSH 1	5/16/1982	Petroleum	12N	26E	12	3342	6822	-3480	B	8
25069211080000	R & A Oil, Inc.	Beihel Rattler #1 21-27	10/10/1984	Petroleum	13N	28E	27	3339	7526	-4187	CF	
25069211090000	R & A Oil, Inc.	State Rattler 1 43-16	7/19/1984	Petroleum	13N	28E	16	3206	7293	-4087	B	8
25069211200000	Black Eagle Operating Co. Inc.	SHARPTAIL 1	9/10/1984	Petroleum	17N	24E	17	3178	6967	-3789		
25069211320000	RME Petroleum Company	COBRA FED 1	11/18/1985	Petroleum	12N	30E	6	2990	8288	-5298	CF	
25069211420000	Mobil Oil Corporation	DOVE F34-30G	5/5/1987	Petroleum	18N	29E	30	2506	7707	-5201	X	8
25071224630000	Wesco Operating, Inc.	Sleeping Buffalo 2-1	5/9/2018	Phillips	32N	32E	1	2287	6951	-4664	X	
25073215230000	Oxy Petroleum Inc	POWERS FA<-29-1	5/19/1981	Pondera	29N	5W	29	3979	5720	-1741	X	
25075050450000	Kirby Royalties	Nash 1	5/5/1965	Powder River	6S	52E	7	3340	9861	-6521	X	6,7
25075220300000	BWAB Incorporated	Orestad-Oddy 6-11	11/28/1979	Powder River	1S	54E	6	2937	9596	-6659	X	7
25083212440000	White Rock Oil & Gas, LLC	Bakken Larson 24-2	3/7/1979	Richland	21N	58E	2	1953	13110	-11157	X	6
25083213200000	Balco Inc.	TOO #1 State 44-16	2/4/1980	Richland	23N	55E	16	2466	12955	-10489	X	6,7
25087051190000	Ohio Oil Company	NPR 1	2/14/1948	Rosebud	10N	39E	9	2919	5913	-2994	X	1,2,8
25087216620000	Macum Energy Inc.	Macum State 14-36	11/6/2000	Rosebud	13N	33E	36	3117	7279	-4162	X	
25089050000000	Premier Petroleum Corp.	Barlett Farm 1	9/13/1953	Sanders	20N	24W	15	2830	210	2620	B	
25089050010000	Premier Petroleum Corp.	Potter 1	7/24/1953	Sanders	23N	24W	11	2882	825	2057	B	
25091050950000	Bensun Energy, LLC	Locks 1 SWD	10/2/1995	Sheridan	36N	52E	35	2443	10795	-8352	X	6,7
25091050980000	Amerada Hess Corporation	JOHNSON 1	10/27/1957	Sheridan	36N	53E	33	2324	10720	-8396	X	7
25091210040000	Farmers Union Central Exch.	NELSON 43X-30	5/16/1967	Sheridan	33N	56E	30	2140	12261	-10121	X	6,7
25091210100000	Legacy Reserves Oper LP	State 2	8/1/1978	Sheridan	33N	58E	16	2025	11861	-9836		
25091212470000	Sun Expl and Prod Inc.	ERDAHL 1	10/8/1980	Sheridan	32N	56E	22	2089	12296	-10207	X	7
25091212500000	Western Meadowlark Res LLC	Tronson 3	12/10/1979	Sheridan	32N	56E	27	2018	11850	-9832	X	7
25091215970000	Wyoming Resources Corp	Federal 36-44R	7/10/2002	Sheridan	32N	54E	36	2125	11856	-9731	X	7
25091217480000	EOG Resources, Inc.	Rovig 1-8	3/25/2000	Sheridan	37N	52E	8	2341	10676	-8335	X	
25095050800000	Mobil Exploration&Production	COPULOS 71 #1	8/20/1953	Stillwater	2N	21E	22	3990	7885	-3895	X	3,6,8
25095210990000	Equitable Res Energy Co.	Brickley 2	5/30/1986	Stillwater	4N	20E	29	4675	6560	-1885	CF	
25099050670000	General Petroleum	Holt 88-30-P 1	10/21/1950	Teton	25N	1W	30	3594	4142	-548	B	2
25099051320000	Conoco Inc.	STATE 1	6/22/1959	Teton	25N	1E	2	3474	3630	-156	B	6
25099054820000	King-Sherwood Oil	State 2	3/17/1984	Teton	26N	1E	34	3480	3363	117	B	6
25099070080000	Cobb, A.B. & Company	HIRSBERG 1	5/19/1944	Teton	27N	4W	23	3852	5112	-1260	X	2
25099211460000	Oxy Petroleum Inc	NEW RCKPRT 26-1	3/10/1981	Teton	24N	3W	26	3954	4395	-441	X	6
25099211610000	Oxy Petroleum Inc	LARSON 1-1	7/19/1981	Teton	22N	5W	1	4178	5844	-1666	X	
25101050510000	Potlatch Oil & Refining Co	ADAMS 1	5/15/1924	Toole	34N	1W	21	3548	3730	-182	X	2
25101052630000	Texaco Expl and Prod Inc.	MOFFATT 1	2/17/1963	Toole	34N	1W	30	3563	4243	-680	X	6
25101067240000	Edwards Etal	Inland Empire 1	12/3/1949	Toole	35N	1W	17	3581	4890	-1309	X	

Table 1—Continued.

API	OPERATOR	WELLNAME	COMPLETION DATE	COUNTY	TWP	RNG	SEC	ELEV KB (ft)	DEPTH PC (ft)	ELEV PC (ft)	Geo Unit	Ref*
2510124000000	New Horizon Resources LLC	Midland 10H	4/27/2006	Toole	36N	2W	25	3527	5095	-1568	X	
25101241920000	Thor Resources USA, LLC	Kevin 33N-01W 04-04	8/8/2012	Toole	33N	1W	4	3476	4446	-970	X	
25101241940000	Thor Resources USA, LLC	Kevin 34N-03W 14-24	1/13/2012	Toole	34N	3W	24	3431	4848	-1417	X	
25101242820000	Avanti Helium US, Inc.	Rankin 1-17		Toole	36N	1E	17	3764	5717	-1953	X	
25103210170000	Southport Exploration, Inc.	TREASURE<-> 1-18	11/24/1984	Treasure	8N	35E	18	2927	7780	-4853	X	
25105050180000	Seaboard Oil	LOBERG 1	4/5/1956	Valley	30N	36E	26	2480	7769	-5289	X	7
25105212000000	Atlantic Richfield Company	FEDERAL 1-3	11/26/1981	Valley	27N	36E	3	2390	7730	-5340	X	7
25105213300000	Phillips Petroleum Company	BERGTOL FED 1-6	10/4/1984	Valley	37N	37E	6	2660	8650	-5990	X	7
25109050180000	Shell Western E & P Inc.	FEDERAL 43-22A	7/26/1955	Wibaux	11N	57E	22	2641	10395	-7754	X	6,7
25111010000000	USGS	Madison 3	5/1/1981	Yellowstone	2N	27E	35	3040	7142	-4102	X	8

Note. Geological Units are: X, Archean "basement"; B, Proterozoic Belt Supergroup; CF, Cambrian Flathead Formation; blank, uncertain. For wells labeled CF, DEPTH PC and ELEV PC are projected from the top of the Cambrian Flathead Fm. Wells highlighted in gray are located in western Montana and outside the study area, but are included for completeness. The two USGS Madison wells were assigned fictitious API numbers for this report.

*References

- 1: Tullis, 1952
- 2: Vine and Erdmann, 1952
- 3: Smith, 1955
- 4: Brown and others, 1977
- 5: Blankennagel and others, 1979
- 6: †Garcia-Ramirez and Helland, 1985
- 7: Sims and others, 1991
- 8: Nelson, 1992

†Several wells listed as "PC" in Garcia-Ramirez and Helland (1985) were determined not to have reached Precambrian rocks.

The geodatabase contains the following elements:

- *Wells*—Well header information and elevations of the top of the Precambrian surface for 115 oil and gas wells in Montana (107 drilled to the Precambrian; 8 drilled to the Cambrian Flathead Fm).
- *PC_Elev_grid*—Precambrian structure grid (2,000-m-square spacing) where X, Y, and Z are longitude, latitude, and elevation of the Precambrian surface.
- *PC_structure_surface*—A raster surface representing the elevation of the Precambrian surface (500 m cell size), interpolated from the elevation grid.
- *PC_structure_contours*—Structure contour lines generated from the grid in PETRA. The contour interval is 500 ft except in some areas of steeply dipping beds where contour intervals were increased to 1,000 ft or 2,000 ft to reduce the number of contour lines.
- *Geology*—Faults and Precambrian outcrop polygons (modified from Vuke and others, 2007).
- *Base layers*—Cities, Counties, and State boundary.

For portability to other software applications, Excel data files are provided for the Precambrian tops interpreted from oil and gas wells (*pc_datapoints_MBMG.xlsx*) and for the Precambrian structure grid (*pc_grid_2000m_MBMG.xlsx*). The structure grid is in XYZ format, where X is longitude, Y is latitude, and Z is elevation of the top Precambrian surface in feet.

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