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BACKGROUND GAMMA RADIATION OF THE TORRINGTON 1° x 2° QUADRANGLE WYOMING AND NEBRASKA

by

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This report has not been reviewed for conformity with the editorial standards of the Geological Survey of Wyoming.

The two maps accompanying this report (Plate 1 and Plate 2) present the natural background gamma radiation in the Torrington 1°x 2° topographic map area, Wyoming and Nebraska. Gamma radiation is the primary component or type of natural ionizing radiation. The other two components, called alpha and beta, are much less energetic and penetrating. Alpha radiation, which consists of particles composed of two protons and two neutrons, can be stopped or shielded by a sheet of paper or plastic wrap. Beta radiation, which consists of particles called electrons, can be shielded by an inch of wood. Gamma radiation, however, can penetrate about three feet of concrete and about 0.25 inch of lead. Other types of ionizing radiation, including x-rays and neutron radiation, are a minor part of cosmic radiation (radiation whose source lies beyond the solar system), and are either totally attenuated by the atmosphere or can pass through the earth without interacting with other substances.

Gamma radiation is a form of electromagnetic radiation characterized by wave lengths from 10^{-7} to 10^{-11} cm and frequencies of 10^{17} to 10^{21} sec^{-1} (Adams and Gasparini, 1970). This places gamma radiation at the short wave and high frequency end of the electromagnetic radiation spectrum that includes infrared and ultraviolet radiation and visible light.

A knowledge of the background radiation of an area may be useful to geologists and land-use planners. For exploration geologists, mineralized areas often exhibit anomalous gamma radiation (either high or low); for environmental planners, local radiation levels may affect a particular development or land use.

The purpose of this study is to provide a reference for expected radiation values. This report is the first of a planned series for each of the sixteen 1° x 2° topographic map sheets that cover Wyoming. Background radiation maps were constructed for each of these maps during the U.S. Department of Energy's National Uranium Resource Evaluation (NURE) program. These latter maps, however, were plotted from information gathered by airborne detectors, which collected this information from altitudes of a few hundred feet. Geologic, atmospheric, and cosmic radiation were blended in a manner so that the NURE maps cannot be used as a guide to local background radiation at the surface of the land. They may, however, be used to locate broad anomalies such as those associated with large bodies of high-background rock and uranium occurrences (Geo Metrics, 1979). In contrast, the two maps of background radiation in this report are based entirely on measurements taken at ground level.

These two maps illustrate background cosmic radiation and terrestrial radiation for the Torrington 1° x 2° map area. Plate 1 shows cosmic radiation. Cosmic radiation intensity is entirely a function of altitude. For this study, values calculated from the work of Herbst (1964) were plotted to the nearest 0.001 milliroentgen per hour (mr/hr). Values in the mapped area range from less than 0.008 mr/hr on the east margin where the North Platte River exits the map area to a high of 0.014 mr/hr at the summit of Laramie Peak. The decrease in cosmic radiation with decreasing elevation is due to attenuation (partial shielding) of the radiation by the atmosphere. Since there is a greater thickness of atmosphere at low altitudes, cosmic radiation is less. As previously noted, other forms of cosmic radiation such as x-rays and ultraviolet radiation are almost completely attenuated.

Plate 2 shows the distribution of gamma radiation from the earth (terrestrial radiation). All substances, including water and the atmosphere, contain trace amounts of radiogenic (radiation-producing) substances which include uranium-238, uranium-235, thorium-232, and potassium-40 and their decay products. The majority of the background gamma radiation, however, comes from earth materials (soil and rock) and is a function of the local geology. This is the greatest source of radiation and also the most variable. Atmospheric inversions can increase the amount of atmospheric radiation by ten times (Pitkin and others, 1964). Such inversions are rare in this area, however, and windless days were not encountered during the course of field measurements. Sampling procedures used in this study would have detected the effects of atmospheric inversion if it had existed. Most water bodies in the area are too small to have much of an effect, and measurements were not made over the largest (Glendo and Guernsey Reservoirs).

Terrestrial radiation was measured at 340 locations (Table 1) in the Torrington 1° x 2° topographic map area, including at least one measurement for every formation and(or) rock type in the area as mapped by Love and others (1980). Terrestrial radiation values for each site were corrected for altitude by subtracting the calculated cosmic values (Herbst, 1964).

Values throughout this study are presented in milliroentgens per hour. These units relate more directly to radiation dose rates (REMs) than other units used in certain studies, such as A.P.I. units or counts per second. REMs are used as units in most radiation-health studies.

The detectors used to measure radiation in the Torrington 1° x 2° map area were a Precision Model 111 scintillator and a McPhar TV-1A spectrometer. The detectors were calibrated for consistent readings using standard procedures involving calibration to a known radiation level (a standard source of gamma radiation was used for this procedure) at each site. One or two readings were taken each day at a base locality near Guernsey (location 26 on Plate 1) to check for minor daily variations in the intensity of cosmic radiation. These variations can be caused by atmospheric inversions or cosmic radiation storms of long duration. During the course of this study, variations encountered at the base station were never greater than 0.002 mr/hr. At each site, all count rates were taken at waist height to insure uniformity.

The background radiation for a given location is calculated by summing the terrestrial radiation (Plate 2) and the cosmic radiation (Plate 1). This value is the total background gamma radiation. Significant discrepancies, either greater or lower than this calculated value, constitute an anomaly, the source of which may then be investigated. Anomalies greater than twice the background level of a formation and(or) rock unit were detected during the course of this study. These are listed in Table 2.

Table 3 presents the values of background radiation from Table 1, grouped according to the surface rock type as mapped by Love and others (1980). The mean value of radiation from each rock unit is also shown as the terrestrial radiation value of each formation and(or) rock type on Plate 2.

Variability within a geologic formation and(or) rock type is due to the distribution of radioactive isotopes within each rock, which can be a function of (1) rock type or (2) local geochemical conditions that produce radioactive isotope depletions or concentrations. Mapped geologic formations and(or) rock units may include many different rock types, such as the Archean rock unit (Wr). This and similar heterogenous rock units have variable background radiation. Other mapped units, such as Quaternary alluvium (Qa), have their sources in many different rock types. Their background radioactivity, while not locally variable, changes from area to area. For example, the radioactivity from alluvium in the

North Platte River Valley above Fort Laramie is lower than that from the Laramie River Valley. Below Fort Laramie, due to the addition of higher background material from the Laramie River, the levels of the background radiation in the North Platte River alluvium are higher than upstream, but not as high as that of the Laramie River alluvium above the confluence. The background gamma radiation of landslide debris (Wls, Plate 2) is totally dependent upon the type of rock material within the unit, i.e., whether it is a mixture of lithologies or a single lithology. Therefore, each landslide has its own background radiation level, and no values are given for this unit on Plate 2 or Table 3.

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Table 1. Terrestrial gamma radiation readings by location number, Torrington 1° x 2° Quadrangle.

Site no.[1]	Location				Formation and(or) rock type[2]	Radiation[3]	REMARKS
1	SENE	sec. 11	T.24N.,	R.61W.	Qal	.026	Platte River alluvium
2	SESW	sec. 5	T.24N.,	R.60W.	Qs	.016	
3	NENE	sec. 22	T.25N.,	R.60W.	Twr	.014	
4	SENW	sec. 27	T.27N.,	R.60W.	Twr	.018	
5	NWNW	sec. 29	T.24N.,	R.60W.	Qal	.023	Platte River alluvium
6	SWNW	sec. 28	T.25N.,	R.61W.	Qal	.022	Platte River alluvium
7	NESWer	sec. 28	T.26N.,	R.61W.	Qs	.015	
8	SWSE	sec. 10	T.26N.,	R.61W.	Twr	.023	
9	NWNE	sec. 33	T.27N.,	R.61W.	Twr	.019	
10	SESE	sec. 14	T.25N.,	R.63W.	Qal	.023	Platte River alluvium
11	SESE	sec. 15	T.25N.,	R.63W.	Qal	.021	Platte River alluvium
12	NESE	sec. 2	T.26N.,	R.64W.	Tml	.023	
13	NWSE	sec. 17	T.28N.,	R.64W.	MDg	.007	
14	NWSE	sec. 17	T.28N.,	R.64W.	Ꞓf[2]	.081[3]	basal contact over P̲Wgd
15	NWSE	sec. 17	T.28N.,	R.64W.	Ꞓf[2]	.012	upper 2 feet of Ꞓf
16	NWSE	sec. 17	T.28N.,	R.64W.	P̲Wqd	.052[3]	top of unit
17	NESW	sec. 17	T.28N.,	R.64W.	P̲Wqd	.035	porphyritic granodiorite
18	NESW	sec. 17	T.28N.,	R.64W.	P̲Wqd	.017	gneiss
21	NWNW	sec. 7	T.27N.,	R.65W.	Ws	.001[3]	iron formation
22	SESW	sec. 2	T.27N.,	R.66W.	Tml	.031	base of unit
23	NWSE	sec. 2	T.27N.,	R.66W.	MDg	.009	
24	NESW	sec. 9	T.27N.,	R.66W.	MDg	.011	
25	SWSW	sec. 27	T.27N.,	R.66W.	Tml	.008	
26	SWNW	sec. 2	T.26N.,	R.66W.	Tml	.017	used as base station
27	NENE	sec. 12	T.26N.,	R.68W.	Tml	.026	surface under cultivation
28	NWNW	sec. 29	T.27N.,	R.68W.	Qal	.020	Cottonwood Creek alluvium
29	NENW	sec. 5	T.27N.,	R.68W.	Tml	.020	
30	NENE	sec. 34	T.28N.,	R.68W.	Tml	.018	
31	SESE	sec. 3	T.28N.,	R.68W.	Twr	.020	
32	SWSW	sec. 18	T.29N.,	R.67W.	Jm	.022	
33	SWSW	sec. 18	T.29N.,	R.67W.	Kcv	.011	
34	SWSW	sec. 16	T.29N.,	R.67W.	Kmt	.011	Muddy Sandstone
35	NENE	sec. 21	T.29N.,	R.67W.	Js	.007	
36	SESE	sec. 5	T.29N.,	R.67W.	Tml	.024	
37	NWNE	sec. 27	T.30N.,	R.67W.	Tml	.024	
38	NWNW	sec. 30	T.30N.,	R.66W.	Tml	.039	
39	SWSW	sec. 23	T.30N.,	R.66W.	Tml	.026	
40	SWSW	sec. 8	T.30N.,	R.65W.	PPh	.014	
41	NWNE	sec. 1	T.30N.,	R.66W.	Tml	.032	
42	SWSE	sec. 24	T.29N.,	R.69W.	TRc	.022	

Table 1. Continued

Site no.[1]	Location		Formation and(or) rock type[2]	Radiation[3]	REMARKS
78	NENW	sec. 5 T.28N., R.69W.	Twr	.035	
79	NWNE	sec. 8 T.28N., R.70W.	Twr	.021	
80	SENE	sec. 13 T.28N., R.71W.	PPc	.027[3]	
81	NWSE	sec. 13 T.28N., R.71W.	Mm	.028[3]	
82	SENE	sec. 13 T.28N., R.71W.	Qal	.032	Horseshoe Creek alluvium
83	NESW	sec. 13 T.28N., R.71W.	Wr	.101	pink granite
84	SENW	sec. 26 T.28N., R.71W.	Wr	.047	white granite
85	SWSE	sec. 34 T.28N., R.71W.	Wr	.065	pink granite
86	NWSE	sec. 11 T.27N., R.71W.	Qt	.055	terrace gravels derived from Wr
87	NWNW	sec. 8 T.27N., R.70W.	Wr	.105	pink granite
88	NESW	sec. 16 T.27N., R.70W.	Wr	.043	gray granite
89	SWSW	sec. 36 T.27N., R.70W.	Tmu	.030	
90	SWNW	sec. 9 T.26N., R.70W.	Qt	.015	
91	SWNE	sec. 16 T.26N., R.70W.	Wr	.017	gneiss
92	SWNE	sec. 22 T.26N., R.70W.	Wr	.055	gneiss
93	SWSW	sec. 36 T.26N., R.70W.	Tmu	.019	
94	NWNE	sec. 34 T.25N., R.69W.	Tmu	.010	
95	SWNW	sec. 17 T.25N., R.69W.	Qal	.013	Wagonhound Creek alluvium
96	NWNW	sec. 16 T.24N., R.70W.	Qt	.011	terrace gravels derived from Wr
97	SWNW	sec. 17 T.24N., R.70W.	Wr	.010	gneiss
98	NESE	sec. 18 T.24N., R.70W.	Wr	.008	gneiss
99	SESE	sec. 4 T.25N., R.62W.	Qal	.013	Rawhide Creek alluvium
00	SWNE	sec. 10 T.26N., R.62W.	Twr	.015	
01	NWNW	sec. 33 T.30N., R.62W.	Tmo	.009	
02	NWNW	sec. 36 T.30N., R.62W.	Tmo	.018	
03	SWSW	sec. 16 T.30N., R.61W.	Tmo	.014	
04	NENE	sec. 2 T.30N., R.61W.	Tmo	.014	
05	SWSW	sec. 36 T.31N., R.61W.	Tmo	.014	
06	NENE	sec. 3 T.30N., R.60W.	Tmo	.017	
07	SESE	sec. 30 T.30N., R.60W.	Tmo	.017	
08	SWSW	sec. 17 T.29N., R.60W.	Tmo	.018	
09	SWSW	sec. 2 T.28N., R.61W.	Tmo	.011	
10	NENW	sec. 21 T.25N., R.61W.	Qs	.015	
26	NWNW	sec. 9 T.30N., R.66W.	Kcv	.007	
27	NESE	sec. 5 T.20N., R.66W.	Jm	.034	
28	SESE	sec. 33 T.30N., R.66W.	Jm	.023	
29	SESE	sec. 35 T.31N., R.66W.	Tmu	.032	
30	SWSW	sec. 36 T.31N., R.66W.	Tml	.030	
31	SWSE	sec. 3 T.30N., R.65W.	PPh	.006	
32	SWSE	sec. 3 T.30N., R.65W.	MDg	.006	
33	NESE	sec. 12 T.30N., R.65W.	PPh	.005	
34	NESE	sec. 12 T.30N., R.65W.	MDg	.009	
35	NENE	sec. 27 T.31N., R.65W.	PPh	.014	
36	SESE	sec. 14 T.31N., R.65W.	Ws	.016	
37	NWNE	sec. 11 T.31N., R.64W.	Tml	.033	granodiorite and amphibolite

Table 1. Continued

Site no.[1]	Location				Formation and(or) rock type[2]	Radiation[3]	REMARKS
138	NWNW	sec. 14	T.31N.,	R.64W.	Ws	.024	
139	SWNW	sec. 14	T.31N.,	R.64W.	Ws	.007	amphibolite
140	SWSE	sec. 22	T.31N.,	R.64W.	Ꞓf[1]	.006	amphibolite
141	SWSE	sec. 22	T.31N.,	R.64W.	Tml	.004	
142	SWSW	sec. 27	T.31N.,	R.64W.	Tml	.016	
143	SWSW	sec. 27	T.31N.,	R.64W.	Red Granite[3]	.101	Mother Featherlegs' Tombstone[4]
144	NESE	sec. 15	T.30N.,	R.64W.	Tml	.024	conglomerate zone
145	NWSE	sec. 23	T.30N.,	R.64W.	Tml	.023	conglomerate zone
146	NWNE	sec. 19	T.30N.,	R.63W.	Tml	.021	
147	NWSW	sec. 31	T.30N.,	R.74W.	Wr	.118	pink granite
148	SWNW	sec. 6	T.33N.,	R.75W.	Kfh	.014	
149	NESW	sec. 2	T.33N.,	R.76W.	Kmv	.025	
150	NWSW	sec. 9	T.33N.,	R.76W.	Kp	.024	
151	SESW	sec. 4	T.33N.,	R.76W.	Qal	.025	Platte River alluvium
152	SESE	sec. 21	T.34N.,	R.76W.	Qs	.012	
153	NESE	sec. 5	T.34N.,	R.76W.	Kl	.012	
154	SWSW	sec. 32	T.35N.,	R.76W.	Kl	.013	
155	NESW	sec. 4	T.33N.,	R.75W.	Kfh	.008	
156	SWSW	sec. 32	T.33N.,	R.75W.	Qt	.024	gravels derived primarily from Wr
157	SENE	sec. 12	T.32N.,	R.76W.	Wr	.046	gneiss
158	NESW	sec. 18	T.32N.,	R.75W.	Wr	.034	gneiss
159	NWSW	sec. 20	T.32N.,	R.75W.	Wr	.020	weathered gneiss
160	NWNW	sec. 6	T.31N.,	R.75W.	Qtcg	.029	
161	SWSW	sec. 7	T.31N.,	R.75W.	Wr	.007	amphibolite
162	NWNW	sec. 17	T.31N.,	R.75W.	Wr	.031	pink granite
163	NENE	sec. 14	T.30N.,	R.76W.	Wr	.059	pink granite
164	SESE	sec. 22	T.30N.,	R.76W.	Wr	.058	pink granite
165	NENE	sec. 2	T.31N.,	R.75W.	PIPc	.003	
166	SESE	sec. 25	T.32N.,	R.75W.	Twr	.029	
167	NWNW	sec. 25	T.32N.,	R.75W.	Wr	.049	gneiss
168	NWSE	sec. 11	T.32N.,	R.75W.	Wr	.046	gneiss
169	NENW	sec. 11	T.32N.,	R.75W.	Ꞓf[1]	.013	
170	NENW	sec. 11	T.32N.,	R.75W.	Mm	.001	
171	NWSW	sec. 2	T.32N.,	R.75W.	PIPc	.004	
172	NWNE	sec. 3	T.32N.,	R.75W.	Twr	.026	
173	SWNE	sec. 27	T.33N.,	R.75W.	Kmv	.009	
174	SWNE	sec. 33	T.34N.,	R.75W.	Kl	.010	
175	SWNE	sec. 33	T.34N.,	R.75W.	Kl	.017	carbonaceous shale
176	NENE	sec. 18	T.34N.,	R.74W.	Tfl	.013	
177	NWNW	sec. 7	T.34N.,	R.73W.	Tfl	.013	
178	SWSW	sec. 15	T.35N.,	R.73W.[5]	Tw	.014	
179	SWNW	sec. 8	T.34N.,	R.73W.	Tfl	.012	
180	NWSW	sec. 29	T.34N.,	R.73W.	Tfl	.009	
181	SENW	sec. 6	T.33N.,	R.73W.	Kl	.012	
182	NWNW	sec. 10	T.33N.,	R.74W.	Qs	.012	

Table 1. Continued

Site no.[1]	Location				Formation and(or) rock type[2]	Radiation[3]	REMARKS
183	SESE	sec. 9	T.33N.,	R.74W.	Qal	.014	North Platte River alluvium
184	NENW	sec. 4	T.32N.,	R.73W.	Twr	.015	
85	NENW	sec. 21	T.32N.,	R.73W.	PPc	.004	
86	SWSW	sec. 16	T.32N.,	R.73W.	Twr	.010	
87	SWSW	sec. 16	T.32N.,	R.73W.	TRc	.014	
88	SWSW	sec. 16	T.32N.,	R.73W.	TRa[5]	.004	
89	SWSW	sec. 16	T.32N.,	R.73W.	TRj[5]	.009	
90	NENW	sec. 16	T.32N.,	R.73W.	Kcv	.016	
91	SENW	sec. 16	T.32N.,	R.73W.	Jm	.028	
92	SENW	sec. 12	T.32N.,	R.73W.	Twr	.028	
93	S 1/2N 1/2	sec. 12	T.32N.,	R.72 1/2W	Twr	.028	
94	NWSE	sec. 5	T.31N.,	R.71W.	Js	.013	
95	SWSE	sec. 5	T.31N.,	R.71W.	Js	.020	Canyon Springs Sandstone Member
96	SWSE	sec. 5	T.31N.,	R.71W.	TRj[5]	.031	
97	NENW	sec. 8	T.31N.,	R.71W.	TRc	.036	
98	SWSW	sec. 8	T.31N.,	R.71W.	Js	.017	Canyon Springs Sandstone Member
99	NENW	sec. 17	T.31N.,	R.71W.	TRPg	.023	
00	SENW	sec. 17	T.31N.,	R.71W.	TRPg	.003	gypsum
01	SENW	sec. 17	T.31N.,	R.71W.	TRPg	.031	
02	SENW	sec. 29	T.31N.,	R.71W.	Jm	.033	
03	SENW	sec. 29	T.31N.,	R.71W.	Kcv	.004	lower sandstone
04	SENW	sec. 29	T.31N.,	R.71W.	Kcv	.022	Fuson Shale[6]
05	SENW	sec. 29	T.31N.,	R.71W.	Kcv	.012	upper sandstone
06	SENW	sec. 29	T.31N.,	R.71W.	Kt	.030	
07	SENW	sec. 29	T.31N.,	R.71W.	Kmt	.013	Muddy Sandstone
08	SENW	sec. 29	T.31N.,	R.71W.	Kmr	.040	
09	NESW	sec. 29	T.31N.,	R.71W.	Kf	.056[3]	lowest black shale
10	NESW	sec. 29	T.31N.,	R.71W.	Kf	.017	
11	SWNW	sec. 36	T.31N.,	R.72W.	Twr	.031	
12	SENW	sec. 2	T.30N.,	R.72W.	Jm	.035	
13	SWNW	sec. 2	T.30N.,	R.72W.	Js	.022	
14	SWNE	sec. 32	T.31N.,	R.72W.	PPc	.007	
15	NWSE	sec. 23	T.31N.,	R.72W.	PPc	.006	
16	NESE	sec. 23	T.31N.,	R.72W.	TRPg	.017	
7	NWNW	sec. 24	T.31N.,	R.72W.	TRPg	.022	
8	NWNW	sec. 24	T.31N.,	R.72W.	TRPg	.002	gypsum
9	SWSW	sec. 13	T.31N.,	R.72W.	Twr	.031	
0	SWNW	sec. 18	T.31N.,	R.71W.	TRc[5]	.021	
1	NWNE	sec. 18	T.31N.,	R.71W.	TRj	.023	
2	SWSW	sec. 6	T.28N.,	R.71W.	Tmu	.054	lower conglomerate
3	SENW	sec. 25	T.28N.,	R.72W.	Wr	.104	pink granite
4	SWNW	sec. 18	T.28N.,	R.71W.	Tmu	.049	lower conglomerate
5	NWSW	sec. 21	T.29N.,	R.71W.	Wr	.040	gray granite
6	SESW	sec. 32	T.31N.,	R.71W.	Kn	.021	
7	SWSW	sec. 27	T.34N.,	R.70W.	Tw	.044	

Table 1. Continued

Site no.[1]	Location	Formation and(or) rock type[2]	Radiation[3]	REMARKS
228	NESW sec. 8 T.33N., R.70W.	Tw	.041	
229	SWNW sec. 25 T.34N., R.70W.	Tw	.039	
230	SENW sec. 9 T.34N., R.69W.	Tfl	.020	
231	SESW sec. 31 T.35N., R.68W.	Tfl	.017	
232	SWSE sec. 34 T.35N., R.68W.	Tfl	.023	
233	SWSW sec. 35 T.35N., R.68W.	Tfl	.019	
234	SWSW sec. 35 T.35N., R.68W.	Tfl	.011	coal outcrop
235	SWNE sec. 31 T.35N., R.67W.	Tfl	.027	
236	SENW sec. 6 T.34N., R.67W.	Tft	.010	white sandstone
237	NWNE sec. 18 T.34N., R.67W.	Tft	.023	claystone
238	NENW sec. 36 T.34N., R.68W.	Tft	.022	
239	NWNE sec. 30 T.33N., R.67W.	Tfl	.023	
240	NWSW sec. 29 T.33N., R.67W.	Tml	.040[3]	
241	SESW sec. 1 T.32N., R.71W.	Tfl	.027	
242	NWNE sec. 9 T.32N., R.70W.	Tfl	.027	
243	SWSW sec. 1 T.32N., R.70W.	Tfl	.027	
244	SWNE sec. 8 T.32N., R.69W.	Tfl	.027	
245	NENE sec. 15 T.32N., R.69W.	Twr	.048	
246	SESE sec. 13 T.32N., R.69W.	Twr	.043	
247	SESE sec. 13 T.32N., R.69W.	Twr	.041	channel sandstone
248	NESE sec. 11 T.33N., R.65W.	Tml	.040[3]	
249	NESE sec. 11 T.33N., R.65W.	Tml	.019	channel sandstone
250	SENW sec. 14 T.34N., R.65W.	Twr	.042	
251	SESE sec. 15 T.35N., R.65W.[5]	Kp	.013	
252	NWNW sec. 6 T.35N., R.65W.[5]	Kfh	.009	
253	SESW sec. 36 T.36N., R.66W.[5]	Kl	.015	
254	NWSW sec. 35 T.36N., R.66W.[5]	Tft	.015	
255	NENW sec. 5 T.35N., R.65W.[5]	Twr	.047	
256	NENW sec. 8 T.34N., R.62W.	Twr	.042	
257	NESW sec. 32 T.35N., R.61W.	Twr	.025	
258	NWNE sec. 15 T.34N., R.60W.	Kp	.011	
259	SESW sec. 30 T.34N., R.60W.	Twr	.025	
260	NWNE sec. 1 T.33N., R.61W.	Tml	.017	
261	NWNW sec. 19 T.33N., R.60W.	Tml	.024	agricultural land
262	SWSW sec. 6 T.33N., R.60W.	Tml	.017	
263	SWSE sec. 18 T.33N., R.61W.	Tml	.019	
264	SWSW sec. 16 T.33N., R.62W.	Tml	.024	agricultural land
265	SESE sec. 15 T.33N., R.63W.	Tml	.025	agricultural land
327	SESE sec. 4 T.27N., R.77W.[5]	Twdr	.032	
328	SWNE sec. 18 T.27N., R.76W.	Twb	.066	
329	SESE sec. 17 T.27N., R.76W.	Twdr	.030	
330	NWSW sec. 22 T.27N., R.76W.	TRPg	.021	Satanka Formation equivalent
331	NENW sec. 26 T.27N., R.76W.	PPc	.0283	
332	NWSW sec. 30 T.27N., R.75W.	Twb	.038	
333	SWNW sec. 29 T.27N., R.75W.	Mm	.010	

Table 1. Continued

Site no.[1]	Location				Formation and(or) rock type[2]	Radiation[3]	REMARKS
334	SWSW	sec. 16	T.27N.,	R.75W.	Wr	.093	pink granite
335	NWNW	sec. 16	T.27N.,	R.75W.	Twdr	.030	
336	NWNE	sec. 16	T.26N.,	R.75W.	Twdr	.015	
337	NENE	sec. 16	T.26N.,	R.75W.	Mm	.010	
338	SENE	sec. 5	T.26N.,	R.75W.	Twb	.023	
339	SENE	sec. 29	T.27N.,	R.75W.	Ws	.103	pink granite
340	SENE	sec. 29	T.27N.,	R.75W.	Ws	.165[3]	limonite-stained pink granite
341	NWSE	sec. 35	T.27N.,	R.76W.	TRPg	.021	Satanka Formation equivalent
342	NWSE	sec. 35	T.27N.,	R.76W.	TRPg	.009	Forelle Limestone equivalent
343	NENW	sec. 2	T.26N.,	R.76W.	Twdr	.028	
344	SWSE	sec. 10	T.26N.,	R.76W.	TRc	.025	
346	SESE	sec. 16	T.26N.,	R.76W.	Jm	.027	
347	SESE	sec. 16	T.26N.,	R.76W.	Jm	.036	freshwater limestone unit
348	SESE	sec. 16	T.26N.,	R.76W.	Kcv	.007	lower sandstone
349	SESE	sec. 16	T.26N.,	R.76W.	Kcv	.004	upper sandstone
350	SWSW	sec. 28	T.26N.,	R.76W.	Kt	.024	
351	SWSW	sec. 28	T.26N.,	R.76W.	Kmt	.007	Muddy Sandstone
352	NENE	sec. 32	T.26N.,	R.76W.	Kf	.026	
353	NENE	sec. 32	T.26N.,	R.76W.	Kf	.019	sandstone unit
354	NWNW	sec. 5	T.25N.,	R.76W.	Qal	.058	playa lake in closed depression[7]
355	SWNW	sec. 18	T.25N.,	R.76W.	Twdr	.035	
356	SENW	sec. 19	T.25N.,	R.76W.	Qp	.026	mixture of Paleozoic and Wr material
357	NWNW	sec. 19	T.25N.,	R.76W.	Kn	.036	
358	SWNE	sec. 35	T.25N.,	R.77W.[5]	Kp	.025	
359	NWNW	sec. 26	T.24N.,	R.77W.[5]	Qpg	.030	mostly Wr material
360	NWSW	sec. 35	T.24N.,	R.77W.[5]	Kmr	.064	bentonite
361	NWSW	sec. 35	T.24N.,	R.77W.[5]	Kmr	.034	
362	NENE	sec. 3	T.23N.,	R.77W.[5]	Kf	.024	
35	SWSW	sec. 36	T.24N.,	R.73W.	Twdr	.015	
36	NWNE	sec. 30	T.24N.,	R.72W.	Ws	.019	gneiss
37	SESE	sec. 17	T.24N.,	R.72W.	Twdr	.016	
38	SESE	sec. 27	T.24N.,	R.73W.	Twdr	.015	
39	NWNW	sec. 14	T.24N.,	R.73W.	Wr	.018	migmatitic gneiss
40	NWNW	sec. 33	T.24N.,	R.73W.	Wr	.016	migmatitic gneiss
41	SWNE	sec. 30	T.25N.,	R.73W.	Ws	.054	pink granite
42	NWNW	sec. 25	T.25N.,	R.74W.	Ꞓf[1]	.022	
43	NENW	sec. 26	T.25N.,	R.74W.	Mm	.003	grey cherty limestone
44	NWNW	sec. 26	T.25N.,	R.74W.	Mm	.003	orange, limonite-stained limestone
45	NWNW	sec. 21	T.25N.,	R.74W.	Twb	.035	
46	SWNE	sec. 17	T.25N.,	R.74W.	Twb	.037	
47	NENE	sec. 5	T.25N.,	R.74W.	Twb	.031	boulder conglomerate unit
48	NWNW	sec. 28	T.26N.,	R.74W.	Twb	.045	
49	SENW	sec. 15	T.26N.,	R.74W.	Twb	.068	boulder conglomerate unit
50	SWNW	sec. 15	T.26N.,	R.74W.	Wr	.133	pink granite
51	SENW	sec. 16	T.26N.,	R.74W.	Twb	.043	

Table 1. Continued

Site no.[1]		Location	Formation and(or) rock type[2]	Radiation[3]	REMARKS
52	SENE	sec. 30 T.25N., R.74W.	Twb	.032	boulder conglomerate unit
53	SWNE	sec. 24 T.24N., R.75W.	Twb	.039	
54	NWSW	sec. 36 T.24N., R.75W.	PPc	.007	bleached white sandstone
55	SWSW	sec. 36 T.24N., R.75W.	PPc	.013	
56	SWNW	sec. 13 T.23N., R.75W.[5]	PPc	.010	
57	NESE	sec. 25 T.23N., R.75W.[5]	TRPg	.018	Satanka Formation equivalent
58	NENE	sec. 28 T.25N., R.66W.	Ws	.067[3]	gneiss
59	SWNE	sec. 22 T.25N., R.66W.	Ws	.062[3]	gneiss
60	NWNE	sec. 28 T.25N., R.66W.	Tml	.025	
61	NENE	sec. 28 T.25N., R.66W.	Tml	.062[3]	basal conglomerate
95	NENW	sec. 2 T.30N., R.64W.	MDg	.016	
96	NWSE	sec. 15 T.28N., R.65W.	Ws	.050	pink granite
97	NENW	sec. 24 T.34N., R.67W.	Tfl	.023	
98	SESE	sec. 19 T.35N., R.65W.	Twr	.063[3]	
99	SESE	sec. 21 T.35N., R.65W.	Twr	.020	
15	SESE	sec. 30 T.24N., R.66W.	Tml	.021	
16	SWSW	sec. 13 T.24N., R.66W.	Qs	.018	
17	NENE	sec. 6 T.24N., R.65W.	Tml	.021	
18	SWSW	sec. 27 T.25N., R.65W.	Tml	.020	
19	SWSW	sec. 30 T.25N., R.64W.	Tml	.018	
20	NENE	sec. 33 T.25N., R.64W.	Qs	.019	
21	SWNW	sec. 30 T.25N., R.63W.	Twr	.025	
22	SWSE	sec. 30 T.25N., R.62W.	Qal	.021	North Platte River alluvium
23	NESE	sec. 31 T.25N., R.62W.	Twr	.023	
24	SWSW	sec. 4 T.24N., R.62W.	Twr	.023	agricultural land
25	NESE	sec. 6 T.26N., R.65W.	Twr	.028	some admixed pediment gravel
26	NWNW	sec. 15 T.26N., R.64W.	Qal	.024	North Platte River alluvium
27	SWSW	sec. 14 T.26N., R.64W.	Qs	.021	
28	NESE	sec. 2 T.26N., R.64W.	Tml	.028	
29	NWNW	sec. 19 T.27N., R.63W.	Qs	.022	
30	SWSW	sec. 33 T.28N., R.63W.	Qs	.022	
31	SWSW	sec. 16 T.28N., R.63W.	Qs	.019	
32	SWSE	sec. 2 T.28N., R.63W.	Tml	.028	
33	NESE	sec. 29 T.29N., R.62W.	Tml	.026	
34	NENE	sec. 3 T.28N., R.62W.	Qs	.020	
35	SESE	sec. 29 T.29N., R.61W.	Qs	.018	
36	NWNW	sec. 16 T.29N., R.61W.	Qs	.016	
37	SWSW	sec. 16 T.30N., R.61W.	Qs	.021	
38	SESE	sec. 32 T.31N., R.61W.	Qs	.019	
39	SWSW	sec. 16 T.31N., R.61W.	Qs	.021	
40	NWSW	sec. 4 T.31N., R.61W.	Tml	.025	
41	NENE	sec. 14 T.33N., R.75W.	Kl	.020	
42	SWNE	sec. 16 T.33N., R.75W.	Kfh	.019	
43	NWSW	sec. 29 T.33N., R.75W.	Kfh	.021	
44	SENW	sec. 18 T.33N., R.75W.	Kfh	.021	

Table 1. Continued

Site no.[1]		Location	Formation and(or) rock type[2]	Radiation[3]	REMARKS
545	NENE	sec. 5 T.32N., R.76W.	Kmv	.027	
546	NWSW	sec. 26 T.33N., R.76W.	Kfh	.019	
547	SWNE	sec. 28 T.34N., R.76W.	Kl	.019	
548	SWSW	sec. 11 T.34N., R.74W.	Tw	.025	
549	SWSW	sec. 4 T.34N., R.73W.	Tw	.023	
550	NWNE	sec. 3 T.34N., R.73W.	Tw	.024	
551	NWNE	sec. 30 T.34N., R.72W.	Tfl	.027	
552	NWSE	sec. 32 T.34N., R.72W.	Tw	.024	
553	NWNW	sec. 10 T.33N., R.72W.	Qal	.018	North Platte River alluvium
554	SWSE	sec. 15 T.33N., R.72W.	Tfl	.024	
559	SWNW	sec. 11 T.27N., R.64W.	Tml	.019	
560	SWNW	sec. 11 T.27N., R.64W.	Qad	.012	
561	NENW	sec. 11 T.27N., R.64W.	Qad	.012	cobble conglomerate
562	NWNW	sec. 11 T.27N., R.64W.	Qad	.012	cobble conglomerate
563	SWNE	sec. 11 T.27N., R.64W.	Qad	.011	white ash and diatomite
564	SENW	sec. 32 T.26N., R.65W.	Tmoc	.011	conglomerate
565	SESW	sec. 4 T.25N., R.65W.	Tmoc	.019	agricultural land
566	SESE	sec. 31 T.25N., R.63W.	Tmoc	.014	siltstone and conglomerate
567	NESE	sec. 6 T.24N., R.63W.	Tmoc	.009	conglomerate-metamorphic rock clasts
568	SWSE	sec. 25 T.25N., R.64W.	Tmoc	.010	conglomerate-metamorphic rock clasts
571	SESE	sec. 26 T.27N., R.66W.	Ws	.017	gneiss
572	SWSE	sec. 13 T.27N., R.66W.	Ws	.023	schist
573	NWNW	sec. 17 T.27N., R.65W.	Ws	.018	gneiss
574	NWNW	sec. 17 T.27N., R.65W.	Ws	.014	metalimestone and metadolomite
575	NWSW	sec. 4 T.27N., R.65W.	Ws	.020	ferruginous quartzite
576	NWSW	sec. 4 T.27N., R.65W.	Ws	.022	grey quartzite
577	NWSW	sec. 4 T.27N., R.65W.	Ws	.025	black schist
578	SWNE	sec. 36 T.27N., R.66W.	Ws	.020	ferruginous quartzite
580	NWNW	sec. 6 T.26N., R.65W.	PWgd	.047	gneiss and quartzite
581	NWNW	sec. 6 T.26N., R.65W.	PWgd	.032	amphibolite and ferruginous schist

[1] Plotted on Plate 1.

[2] From Love and others, 1980.

[3] Background gamma radiation level corrected for elevation.

[4] Ꞓf (Flathead Formation) mapped with the Mississippian Madison and Missisippian-Devonian Guernsey Limestones by Love and others (1980).

[5] Anomalous reading (see Table 2).

[6] Rock imported from elsewhere. Location not included in other calculations.

[7] Data point outside of map area. Information used to calculate mean background of rock unit. (Table 3).

[8] T a and T j (Alcova Limestone and Jelm Formation) not mapped separately, but included in the Chugwater Formation.

[9] Not included in calculations of background radiation for the Cloverly Formation.

[10] Not included in calculations of background radiation for Quaternary alluvium.

Table 2. Gamma radiation anomalies, Torrington 1° x 2° Quadrangle.

Site No.	Location[1]	Measured radio-activity (mr/hr)	Background radioactivity for unit[2] (mr/hr)	Measured radio-activity as a function of the normal background radition[3]
14	sec. 17 T.28N., R.64W	.081	.013(Ꞓf)	6.2X
21	sec. 2 T.27N., R.65W.	.001	.033(P̲Wgd)	-33:0X
80	sec. 13 T.28N., R.71W	.027	.007(P̄ℙc)	3.9X
81	sec. 13 T.27N., R.71W.	.028	.005(Mm)	5.6X
189	sec. 16 T.32N., R.73W.	.009	.026(TRc)	-2.9X
209	sec. 29 T.31N., T.71W.	.056	.022(Kf)	2.5X
331	sec. 26 T.27N., T.76W.	.028	.007(Pℙc)	4.0X
458	sec. 28 T.25N., R.66W.	.067	.026(Ws)	2.6X
459	sec. 22 T.25N., R.66W.	.062	.026(Ws)	2.4X
461	sec. 28 T.25N., R.66W.	.062	.021(Tml)	3.0X
498	sec. 19 T.35N., R.65W.	.063	.026(Twr)	2.4X

1 See Plate 1 and Table 1.

2 For explanation of formation and(or) rock unit abbreviations, see Plate 2.

3 Anomalies are 2X background radiation or greater.

Table 3. Terrestrial gamma radiation readings grouped by formation and(or) rock type.

Qa, Ql, Qls

No.[1]	Radiation[2]
1	.026
5	.023
6	.022
10	.023
11	.021
28	.020
82	.032
95	.031
99	.013
151	.025
354	.058[3]
522	.021
526	.024
553	.018
558	.022

average = .022

Qt, Qp

No.[1]	Radiation[2]
86	.040
90	.015
96	.011
156	.024
356	.026
359	.030

average = .024

Qs, Qsl

No.[1]	Radiation[2]
2	.016
7	.015
110	.015
152	.012
182	.012
516	.018
520	.019
527	.021
529	.022
530	.022
531	.019
534	.020
535	.018
536	.016
537	.021
538	.019
539	.021

average = .018

Qad

No.[1]	Radiation[2]
560	.012
561	.012
562	.012
563	.011

average = .012

QTcg

No.[1]	Radiation[2]
160	.029

Tmu

No.[1]	Radiation[2]
89	.030
93	.019
94	.010
120	.032
222	.055
224	.049

average = .032

Tml

No.[1]	Radiation[2]
12	.023
22	.031
25	.008
26	.017
27	.026
29	.020
30	.018
36	.024
37	.024
38	.039
39	.026
41	.032
101	.009
102	.018
103	.014
104	.014
105	.014
106	.017
107	.017
108	.018
109	.011
130	.030
138	.016
142	.016
144	.024

Tml continued

No.[1]	Radiation[2]
145	.023
146	.021
240	.040
248	.040
249	.019
260	.017
261	.024
262	.017
263	.019
264	.024
265	.025
460	.025
461	.062[4]
515	.021
517	.021
518	.020
519	.018
528	.028
532	.028
533	.026
540	.025
559	.014

average = .021

Tmoc

No.[1]	Radiation[2]
564	.011
565	.019
566	.014
567	.009
568	.010

average = .013

Twr

No.[1]	Radiation[2]
3	.014
4	.018
8	.023
9	.019
31	.020
78	.035
79	.021
100	.015
166	.029
172	.026
184	.015
186	.010
192	.028

Table 3 continued

No.[1]	Radiation[2]
Twr continued	
193	.028
211	.031
219	.031
239	.023
245	.048
246	.043
247	.041
250	.042
255	.047
256	.042
257	.025
259	.025
498	.063[4]
499	.020
521	.025
523	.023
524	.022
525	.028
average =	.026
Twb	
328	.066
332	.038
338	.023
445	.035
446	.037
447	.031
448	.045
449	.068
451	.043
452	.032
453	.039
average =	.042
Tw	
178	.014
227	.044
228	.041
229	.039
548	.025
549	.023
550	.024
552	.024
average =	.030

No.[1]	Radiation[2]
Twdr	
327	.032
329	.030
335	.030
336	.015
343	.028
355	.035
435	.015
437	.016
438	.015
average =	.023
Tfl	
176	.013
177	.013
179	.012
180	.009
230	.020
231	.017
232	.023
233	.019
234	.011[5]
235	.027
239	.023
241	.027
242	.027
243	.027
244	.027
497	.023
551	.027
554	.024
average =	.021
Tft	
236	.010
237	.023
238	.022
254	.015
average =	.018

No. 1	Radiation[2]
Kl	
153	.012
154	.013
174	.010
175	.017
181	.012
253	.015
541	.020
547	.019
average =	.015
Kfh	
148	.014
155	.008
252	.009
542	.019
543	.021
544	.021
546	.019
average =	.016
Kp, Kc	
150	.024
251	.013
258	.011
358	.025
average =	.018
Kmv	
149	.025
173	.009
545	.027
average =	.020
Kn	
226	.021
357	.036
average =	.029

Table 3 continued.

Kf

No.[1]	Radiation[2]
209	.056[4]
210	.017
352	.026
353	.019
362	.024
average =	.022

Kmt-Kt[6]

No.[1]	Radiation[2]
34	.011
206	.030
207	.013
350	.024
351	.007
average =	.017

Kmt-Kmr[6]

No.[1]	Radiation[2]
208	.040
360	.064
361	.034
average =	.046

KJ-Kcv-Kik[6]

No.[1]	Radiation[2]
33	.011
126	.007
190	.016
203	.004
204	.022[7]
205	.012
348	.007
349	.004
average =	.009

KJ-Jm[6]

No.[1]	Radiation[2]
32	.022
127	.034
128	.023
191	.028
202	.033
212	.035
346	.027
347	.036
average =	.030

Js

No.[1]	Radiation[2]
35	.007
194	.013
195	.020
198	.017
213	.022
345	.018
average =	.016

TRc

No.[1]	Radiation[2]
42	.022
187	.014
188	.004[9]
189	.009[4]
196	.031
197	.036
220	.021
221	.023
344	.025
average =	.023

TRPg

No.[1]	Radiation[2]
199	.023
200	.003[8]
201	.031
216	.017
217	.022
218	.002[8]
330	.021
341	.021
342	.009[8]
457	.018
average =	.022
average gypsum[8] =	.003

PPh

No.[1]	Radiation[2]
400	.014
131	.006
133	.005
134	.009
136	.016
average =	.010

PPc

No. 1	Radiation[2]
80	.027[4]
165	.003
171	.004
185	.004
214	.007
215	.006
331	.028[4]
454	.007
455	.013
456	.010
average =	.007

Mm

No. 1	Radiation[2]
81	.021[4]
170	.004
333	.010
337	.010
443	.003
444	.003
average =	.005

MDg

No. 1	Radiation[2]
13	.007
23	.009
24	.011
132	.006
135	.014
495	.010
average =	.011

Ꞓf[10]

No. 1	Radiation[2]
14	.081[4]
15	.012
141	.004
169	.013
442	.022
average =	.013

Table 3 continued

No.[1]	Radiation[2]
	PWgd
16	.052[4]
17	.035
18	.017
21	.001
580	.047
581	.032
average =	.033
	Ws
137	.033
139	.007[11]
140	.006[11]
458	.067[4]
459	.062[4]
496	.050
571	.017
572	.023
573	.018
574	.014
575	.020
576	.021
577	.025
578	.020
average =	.026

No.[1]	Radiation[2]
	Wr
83	.101[12]
84	.047[13]
85	.065[12]
87	.105[12]
88	.043[13]
91	.019[14]
92	.055[14]
97	.010[14]
147	.118[12]
157	.046[14]
158	.034[14]
159	.020[14]
161	.007[11]
162	.031[12]
163	.059[12]
164	.058[12]
167	.049[14]
168	.046[14]
223	.104[12]
225	.040[13]
334	.093[12]
339	.103[12]
340	.165[12]
436	.019[14]
439	.018[14]
440	.016[14]
441	.054[12]
450	.133[12]
average of all Wr	.059
average of pink granite	.091
average of gray granite	.043
average of gneiss	.030
amphibolite	.007

Table 3 continued

[1] Refers to site locations, Plate 1.

[2] Units are milliroentgens per hour (mr/hr)

[3] Playa deposit, not included in calculations

[4] Anomaly (see Table 1), not included in calculations

[5] Coal bed

[6] Units given separately due to large difference in background radioactivity

[7] Fuson Shale, not included in calculations

[8] Gypsum beds calculated separately

[9] Alcova Limestone, not included in calculations

[10] Flathead Formation, not shown on Plate 2

[11] Amphibolite

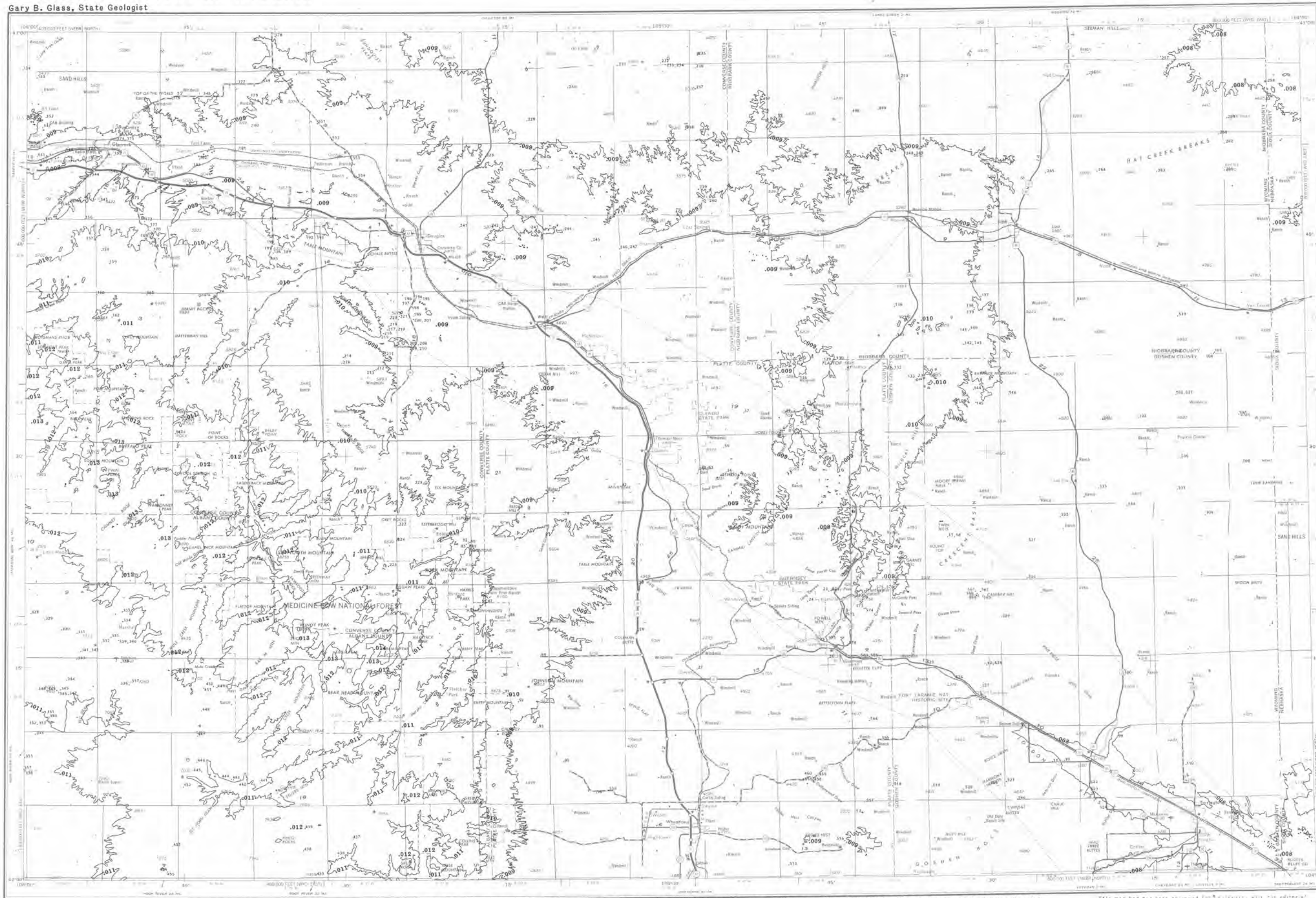
[12] Pink granite calculated separately

[13] Grey granite calculated separately

[14] Gneiss calculated separately

GEOLOGICAL SURVEY OF WYOMING

Gary B. Glass, State Geologist



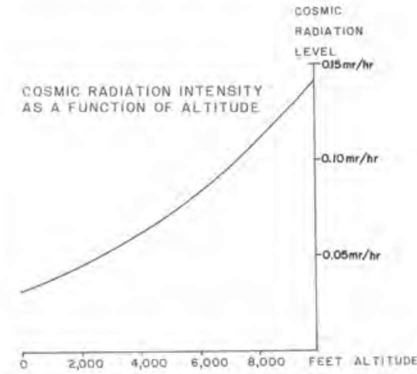
EXPLANATION

.012 Cosmic radiation background (milliroentgens per hour)

11 Sample locality

Note - sample locality numbers are not in sequence

Cosmic radiation levels calculated from Herbst (1964), plotted to the nearest 200-foot contour line:



(Modified from Herbst (1964))

COSMIC RADIATION LEVELS AND SAMPLE LOCALITIES, BACKGROUND GAMMA RADIATION OF THE TORRINGTON 1° by 2° MAP AREA, WYOMING AND NEBRASKA

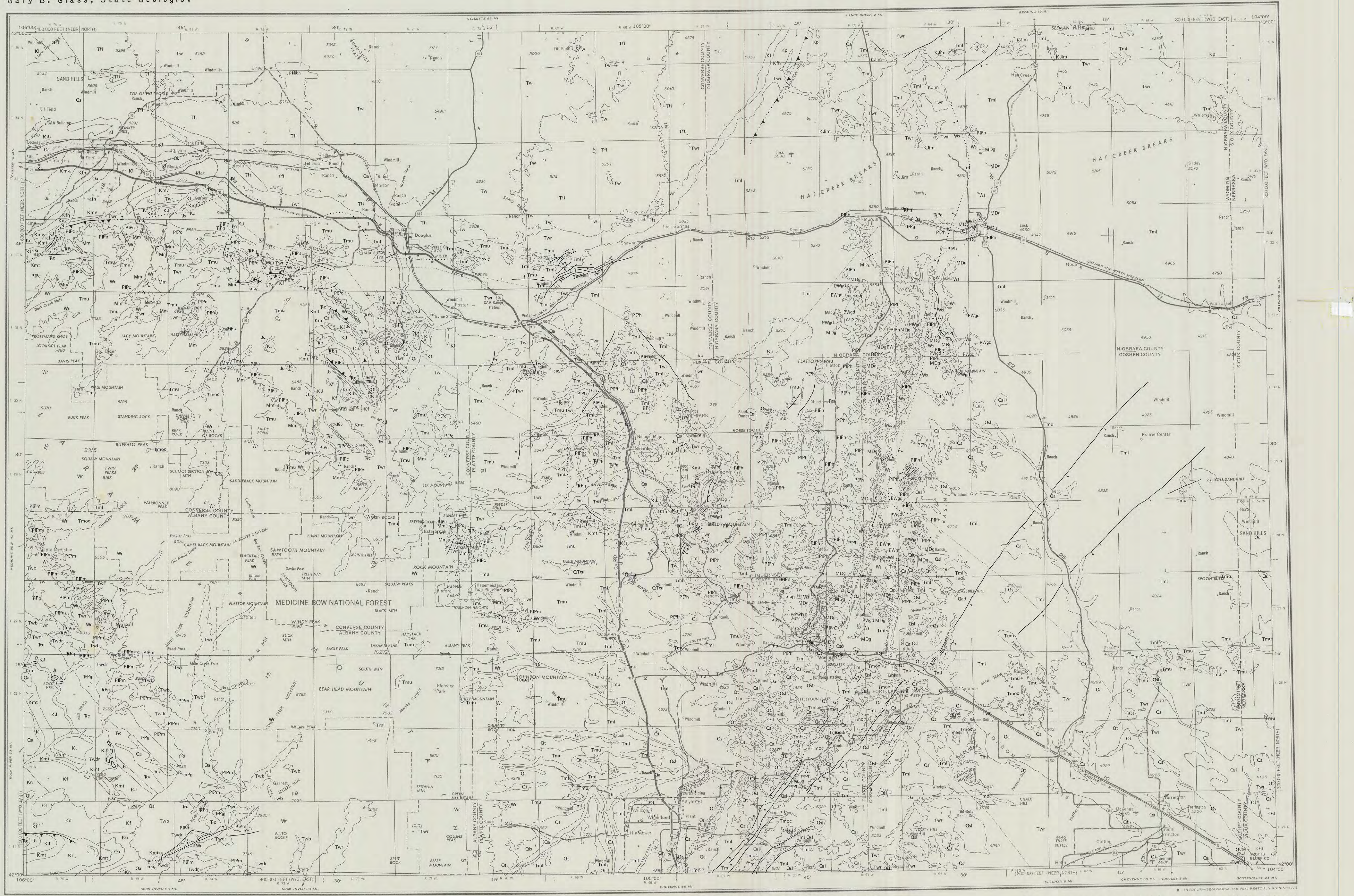
by

Ray E. Harris 1985

This map has not been reviewed for conformity with the editorial standards of the Geological Survey of Wyoming

5 0 5 10 MILES

5 0 5 10 15 20 25 KILOMETERS



TERRESTRIAL RADIATION LEVELS, BACKGROUND GAMMA RADIATION OF THE TORRINGTON 1° BY 2° MAP AREA, WYOMING AND NEBRASKA

by

Ray E. Harris 1985

This map has not been reviewed for conformity with the editorial standards of the Geological Survey of Wyoming

5 0 5 10 15 20 MILES
5 0 5 10 15 20 25 30 KILOMETERS
1:250,000

EXPLANATION

Contact

Thrust fault -- dashed where approximately located. Sawteeth on upper plate.

Fault -- dotted where concealed. Bar and ball on downthrown side.

Strike-slip fault -- arrows indicate relative direction of movement.

BACKGROUND GAMMA RADIATION LEVELS (milliroentgens per hour)

- 0.050 mr/hr or greater
- 0.040 - 0.049 mr/hr
- 0.030 - 0.039 mr/hr
- 0.020 - 0.029 mr/hr
- 0.010 - 0.019 mr/hr
- 0.009 mr/hr or less

No patterns or colors are used on this Open File map. The map may be hand-colored, **however, by coloring each formation and rock type in accordance with the mean background gamma radiation tabulated below.**

DESCRIPTION OF MAP UNITS AND MEAN BACKGROUND GAMMA RADIATION LEVEL in milliroentgens per hour (mr/hr)

Desciptions from Love, Christiansen, and Sever, 1980. The Miocene-Pliocene boundary follows the European convention for marine rocks (Berggren and Van Couvering, 1974), at five million years before present.

SURFICIAL DEPOSITS (HOLOCENE AND PLEISTOCENE)

Qa (.022) Alluvial deposits -- Unconsolidated and poorly consolidated clay, silt, sand, and gravel. Deposited mainly in flood plains and low terraces.

Qt (.024) Terrace gravel -- Pebble, cobble, and boulder deposits containing some clay, silt, and fine sand on high terraces.

Qsl (.018) Sand and loess -- Fine residual sand and loess on drainage divides

Qs (.018) Dune sand -- Fine windblown sand.

Qls Landslide deposits -- Unsized and unsorted rock debris emplaced by mass movement.

Ql (.022) Playa deposits -- Highly alkaline clay with lesser amounts of sand. Present in Tps.24-25N., R.76W.

Qp (0.24) PEDIMENT DEPOSITS (PLEISTOCENE) -- Angular blocks of Paleozoic and Precambrian rock. Present in Tps.27-28N., R.65W.

Qad (.012) DEPOSITS ON CASEBIER HILL (PLEISTOCENE) -- Lacustrine clay, white diatomite, and ash intertonguing with sand and gravel. Present in T.27N., R.65W. Thickness 0-50 ft.

QTcg (.029) PLEISTOCENE(?) to MIOCENE(?) CONGLOMERATE -- Giant boulders, as large as 16 ft, of granite in brown arkosic matrix, overlapping lower Miocene sandstones in Tps.27-28N., Rs.68-69W. Present only on high interstream divides extending east from Laramie Mountains. Age uncertain. Thickness 0-100 ft.

Tmu (.032) UPPER MIOCENE ROCKS -- Fine- to coarse-grained, light-gray to greenish-, yellowish-, and orange-gray sandstone interbedded and interfingered in upper part with conglomerate, claystone, and fresh-water limestone. White to dark-gray, vitric tuff beds near top. Lower part has hard, "pipy," calcareous sandstone concretions. Thickness 345-607 ft.

Tml (.021) LOWER MIOCENE ROCKS -- Light-gray to buff, fine-grained, poorly bedded sandstone containing abundant magnetite grains. Some siltstone, limestone, and tuff. Lenticular conglomerate near base. Thickness 0-705 ft.

Tmoc (.013) MIOCENE(?) and OLIGOCENE(?) CONGLOMERATE --Light-gray conglomerate with clasts of Precambrian rocks, interbedded with blocky, brown and gray claystone like that in underlying White River Formation (Twr). Thickness 0-490 ft.

Twr (.026) WHITE RIVER FORMATION (OLIGOCENE) -- White to pale-pink and pale-green tuffaceous, bentonitic claystone, which breaks with characteristic conchoidal fracture. Lenses of gray sandstone and arkosic conglomerate. Thickness 0-1,510 ft.

Twb (.042) WAGON BED FORMATION (MIDDLE EOCENE) -- Green and pink, soft, bentonitic claystone and tuffaceous brown sandstone and conglomerate with bentonitic matrix. Giant granite boulders as large as 16 ft abundant. Present only on west side of Laramie Mountains. Thickness 0-150 ft.

Twdr (.023) WIND RIVER FORMATION (LOWER EOCENE) -- Brown, yellow, greenish-gray, and variegated claystone, brown to gray sandstone, and thin conglomerates; distinguished from Wagon Bed Formation by its lack of bentonitic and other abundant tuffaceous material. Present only on west side of Laramie Mountains 0-425 ft.

Tw (.030) WASATCH FORMATION (EOCENE) -- Buff, arkosic sandstone, lenticular conglomerate, drab siltstone, carbonaceous shale, and many coal beds. Some variegated mudstone. Thickness 0-2,000 ft).

FORT UNION FORMATION (PALEOCENE)

Tfl (.021) Lebo Member -- Fine- to coarse-grained, drab to gray sandstone, finely conglomeratic in part, interbedded with drab siltstone, claystone, shale, and thin coal beds. Thickness 0-2,490 ft.

Tft (.018) Tullock Member -- Drab to gray and contains massive, light-gray sandstones, whereas the Lebo Member is darker and contains more shale and claystone. Thickness 0-1,510 ft.

Kl (.015) LANCE FORMATION (UPPER CRETACEOUS) -- Somber shale and drab, massive, lenticular, concretionary sandstone. Many thin coal beds in lower half. Thickness 2,000-2,490 ft.

Kfh (.016) FOX HILLS SANDSTONE (UPPER CRETACEOUS) -- White to light-gray sandstone and gray sandy shale containing marine fossils. Thickness 148-197 ft.

Kp (.018) PIERRE SHALE (UPPER CRETACEOUS) -- Dark-gray to black concretionary marine shale. Includes Red Bird Silty Member in middle part and Sharon Springs Member near base. Many bentonite beds. Thickness 2,000-3,100 ft.

Kmv (.020) MESAVERDE FORMATION (UPPER CRETACEOUS) -- At top, white Teapot Sandstone Member, underlain by gray sandstone, shale, and coal member. Nonmarine, gray Parkman Sandstone Member at base. Thickness 600-1,200 ft.

Kc (.018) CODY SHALE (UPPER CRETACEOUS) -- Gray to black, soft, limy marine shale and thin bentonite beds. Lenticular sandstone common in upper part. Thickness 3,000-4,500 ft.

Kn (.029) NIOBRARA FORMATION (UPPER CRETACEOUS) -- Dark-gray to black concretionary shale and light-gray to yellow, chalky limestone. Upper limestone very seleniferous. Thickness 558-590 ft.

Kf (.022) FRONTIER FORMATION (UPPER CRETACEOUS) -- Dark-gray and black shale with thin concretionary sandstone. Wall Creek Sandstone Member at top. Thickness 590-705 ft.

Kmt MOWRY AND THERMOPOLIS SHALES (LOWER CRETACEOUS)

Kmr (.046) Mowry Shale -- Dark-gray to black, siliceous, hard shale; weathers silvery gray and contains abundant fish scales. Thickness 80-148 ft.

Kt (.017) Thermopolis Shale -- Black, fissile shale with thin, cream-colored bentonite beds and bentonitic partings. Muddy Sandstone Member at top. Thickness 148-245 ft.

KJ CLOVERLY AND MORRISON FORMATIONS

Kcv (.009) Cloverly Formation (Lower Cretaceous) -- Upper shaly, gray, ferruginous sandstone, underlain by gray to variegated claystone. At base is buff-weathering gray sandstone with chert-pebble conglomerate lenses. Thickness 148-312 ft.

Jm (.030) Morrison Formation (Upper Jurassic) -- Dully variegated, silty claystone; freshwater limestone; and lenticular, yellow to gray sandstone. Thickness 98-295 ft.

KJim INYAN KARA GROUP AND MORRISON FORMATION

Kik (.009) Inyan Kara Group (Lower Cretaceous) -- Similar to Cloverly Formation in lithology and thickness

Jm (.030) Morrison Formation (Upper Jurassic) -- see description above under CLOVERLY AND MORRISON FORMATIONS.

Js (.016) SUNDANCE FORMATION (UPPER AND MIDDLE JURASSIC) -- Green to greenish-gray, glauconitic sandstone and shale underlain by gray, green, and red, nonglauconitic sandstone and shale. Canyon Springs Sandstone Member, 149-149 ft. thick, at base. Total thickness 260-475 ft.

TRc (.023) CHUGWATER FORMATION (UPPER(?) TO LOWER TRIASSIC) -- Red siltstone, shale, and silty sandstone, with thin gypsum partings and seams. Thickness 148-492 ft. in Glendo-Hartville area, 656-853 ft. in southwestern part of quadrangle.

TRPg (.022) GOOSE EGG FORMATION (LOWER TRIASSIC TO LOWER PERMIAN) -- Interbedded red to ocher shale and siltstones, thin limestone, limestone breccia, and gypsum beds (Gypsum = 0.003 mr/hr). Thickness 197-345 ft.

PIPh (.010) HARTVILLE FORMATION (LOWER PERMIAN AND PENNSYLVANIAN) -- Light-gray, massive limestone and dolomite, cherty in part, with some red and light-gray, calcareous sandstone and siltstone. Locally cavernous and brecciated in upper part. Quartzitic sandstone at base. Thickness 853-1,230 ft.

PIPm (.006) CASPER FORMATION AND MADISON LIMESTONE -- Locally, map unit may include some Cambrian rocks. Thickness 500-950 ft.

PIPc (.007) Casper Formation (lower Permian and Upper and Middle Pennsylvanian) -- Red, buff, and gray, feldspathic to quartzose sandstone with conspicuous festoon cross-lamination interbedded with thin light-colored fossiliferous limestone and red shales. Thickness 558-804 ft.

Mm (.005) Madison Limestone (Lower Mississippian) -- Blue-gray, massive, cavernous, cherty limestone and dolomite. Local arkosic sandstone at base of mapped unit may be Cambrian. Thickness 0-345 ft.

MDg (.011) GUERNSEY FORMATION (LOWER MISSISSIPPIAN AND UPPER DEVONIAN) -- Upper part is hard, gray, cherty, coarsely crystalline limestone. Lower part is thin-bedded, brittle, silty, purple to gray dolomite with basal arkose or quartzite containing Late Devonian marine fossils. Thickness 148-246 ft.

PWgd (.033) GRANITE AND QUARTZ MONZONITE (PROTEROZOIC AND ARCHEAN) AND DIORITE (PROTEROZOIC) -- Includes mixed Proterozoic (Haystack Range) and Archean (Rawhide Mountains) granite and quartz monzonite, and some roof pendants of Archean(?) metasedimentary rock.

Ws (.026) ARCHEAN(?) METASEDIMENTARY AND METAVOLCANIC ROCKS -- Muscovite, actinolite, and biotite schists, quartzite; greenstone; and pink, gray, and brown dolomite. Includes pegmatite and amphibolite intrusives.

Wr (.059) ARCHEAN GRANITE AND AMPHIBOLITE -- Includes minor Archean(?) metasediments and peridotite in T.27N., R.70W. Rb/Sr ages range from 2,480±42 to 2,715±35 m.y. (Hills and Houston, 1979, p. 81).

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