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Energy Systems Environmental Restoration Program

Geology Summary of Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee

J. E. Anderson

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ABBREVIATIONS/DEFINITIONS

BNI	Bechtel National, Inc.
Cm	Maryville Limestone
Cn	Nolichucky Shale
cps	counts per second
Cpv	Pumpkin Valley Shale
Crg	Rogersville Shale
Crt	Rutledge Limestone
multiport wells	Multiport wells are designed to allow multi-level sampling and monitoring. Any number of monitoring zones can be installed in a single borehole.
ORR	Oak Ridge Reservation
WAG	Waste Area Grouping
Waste Area Grouping	All known active and inactive waste areas, contaminated facilities, and potential sources of continuing release to the environment at Oak Ridge National Laboratory have been categorized into Waste Area Groupings, each of which contains sites within geographically and/or hydrologically defined units. The WAG concept was developed to subdivide the remedial action sites into manageable units that could be handled separately.

EXECUTIVE SUMMARY

During FY 1994, three multiport wells were installed in Waste Area Grouping (WAG) 5. The wells were instrumented with Westbay multiport systems. The purpose of the wells is (1) to characterize different flow systems and (2) to monitor for contaminants. The geology of the individual boreholes (WAG 5-12, WAG 5-13, WAG 5-14) is documented in Bechtel National, Inc., (BNI) et al. (1994). BNI et al. (1994) does not explicitly show geologic relationships between these boreholes or integrate this information into the geology of WAG 5. The purpose of this report is to document and present a summary of the distribution of geologic formations in WAG 5. This information is presented in several ways: (1) stratigraphic correlation diagrams based on the natural gamma ray log, (2) geologic cross sections, and (3) a geologic map. This work provides a reference frame for interpreting flow, water, and contaminant chemistry data from multiport wells.

1. INTRODUCTION

During FY 1994, three multiport wells were installed in Waste Area Grouping (WAG) 5. Well locations are shown in Fig. 1. The wells were instrumented with Westbay multiport systems. The purpose of the wells is (1) to characterize different flow systems and (2) to monitor for contaminants. The geology of the individual boreholes (WAG 5-12, WAG 5-13, WAG 5-14) is documented in Bechtel National, Inc., (BNI) et al. (1994). BNI et al. (1994) does not explicitly show geologic relationships between these boreholes or integrate this information into the geology of WAG 5. The purpose of this report is to document and present a summary of the distribution of geologic formations in WAG 5. This work provides a reference frame for interpreting flow, water, and contaminant chemistry data from multiport wells.

General geologic information about stratigraphic units in WAG 5 can be found in Hatcher et al. (1992). Geologic formations in WAG 5 consist of Cambrian-age Conasauga Group and include Pumpkin Valley Shale (Cpv), Rutledge Limestone (Crt), Rogersville Shale (Crg), Maryville Limestone (Cm) and Nolichucky Shale (Cn). Construction and installation information for multiport wells is presented in BNI et al. (1994). Geophysical logging was done for each well and the cores were described. Based on geophysical logs, contacts between stratigraphic formations were determined and multiple sampling zones were chosen for each well (BNI, 1994).

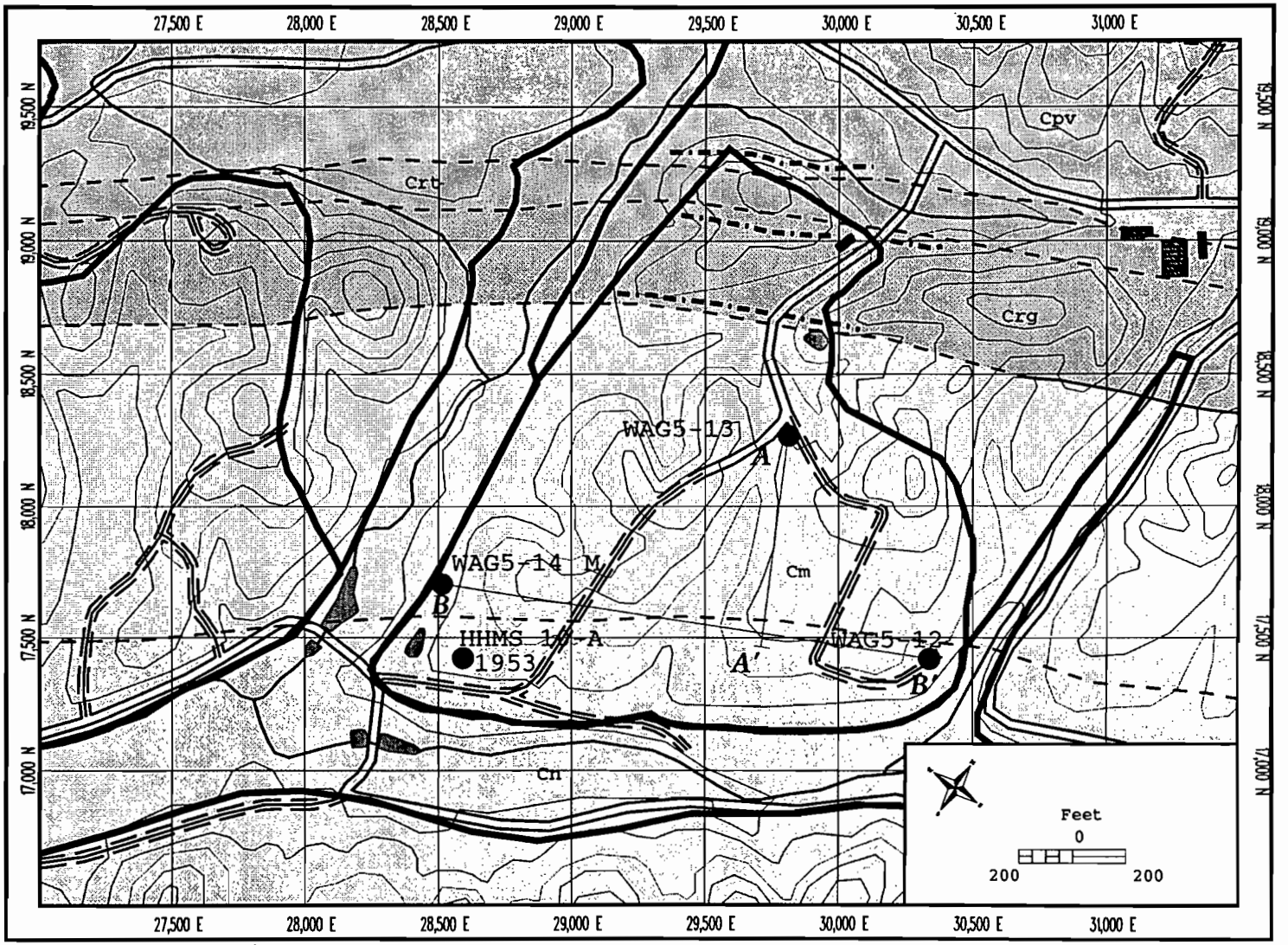

Fig. 1. Westbay Well location map by Lemiszki (Hatcher et al., 1992). Original contacts are shown by dashed lines. Our contacts are shown by the dash-dot lines for WAG 5 only. AA' and BB' = lines of the cross section.

2. METHODS

Geologic information in this report is presented in several ways:

1. **Stratigraphic correlation diagrams based on the natural gamma ray log.** A natural gamma log easily distinguishes individual beds of shale and limestone. In addition, geophysical descriptions of geology on the Oak Ridge Reservation (ORR) are already available (Hatcher et al., 1992), so we can compare geophysical logs from WAG 5 wells with those presented in that report. To make decisions and distinguish the beds, we (1) observe baseline trends on gamma ray log diagrams (i.e., we observe and contrast both gradual and abrupt shifts in the average gamma ray value) and (2) compare the values of the gamma logs [counts per second (cps)]. The same formations should show similar values in wells that are similarly constructed.

2. **Geologic cross sections.** To construct geologic cross sections, we first determined strike and dip of the beds in WAG 5. For that purpose, we used the standard three point problem solution, which determines dip and strike from three points each with different elevations (Ragan, 1973). Then we constructed a strike-perpendicular cross section and projected data onto the line of section.

3. **Geologic maps.** A geologic map of WAG 5 is included in the ORR map prepared by Peter Lemiszki and is presented in Hatcher et al. (1992). This map is based on surface geologic data. We tried to integrate surface and subsurface geologic data so that they are internally consistent.

3. RESULTS

3.1 STRATIGRAPHIC CORRELATION DIAGRAMS

There are two versions of the stratigraphic correlation of WAG 5 geologic units. One of them is presented in BNI et al. (1994) and is based on work done by J. Smith in 1994. We suggest another version which is presented in this work. The BNI/Smith version is shown on Fig. 2. Figure 3 shows our version. The major contacts according to our version are given in Table 1.

Table 1. Stratigraphic contact depth in feet*

	WAG5-12	WAG5-13	WAG5-14
Top of Cm (lower)	265	NA	185
Top of Crg	380	184	326
Top of Crt	470	310	451
Top of Cpv	NA	484	NA

*Depth is given in feet below ground surface, measured along the borehole.

Symbols: Cm (lower) – lower Maryville Limestone, Crg – Rogersville Shale, Crt – Rutledge Limestone, Cpv – Pumpkin Valley Shale.

NA = Not available.

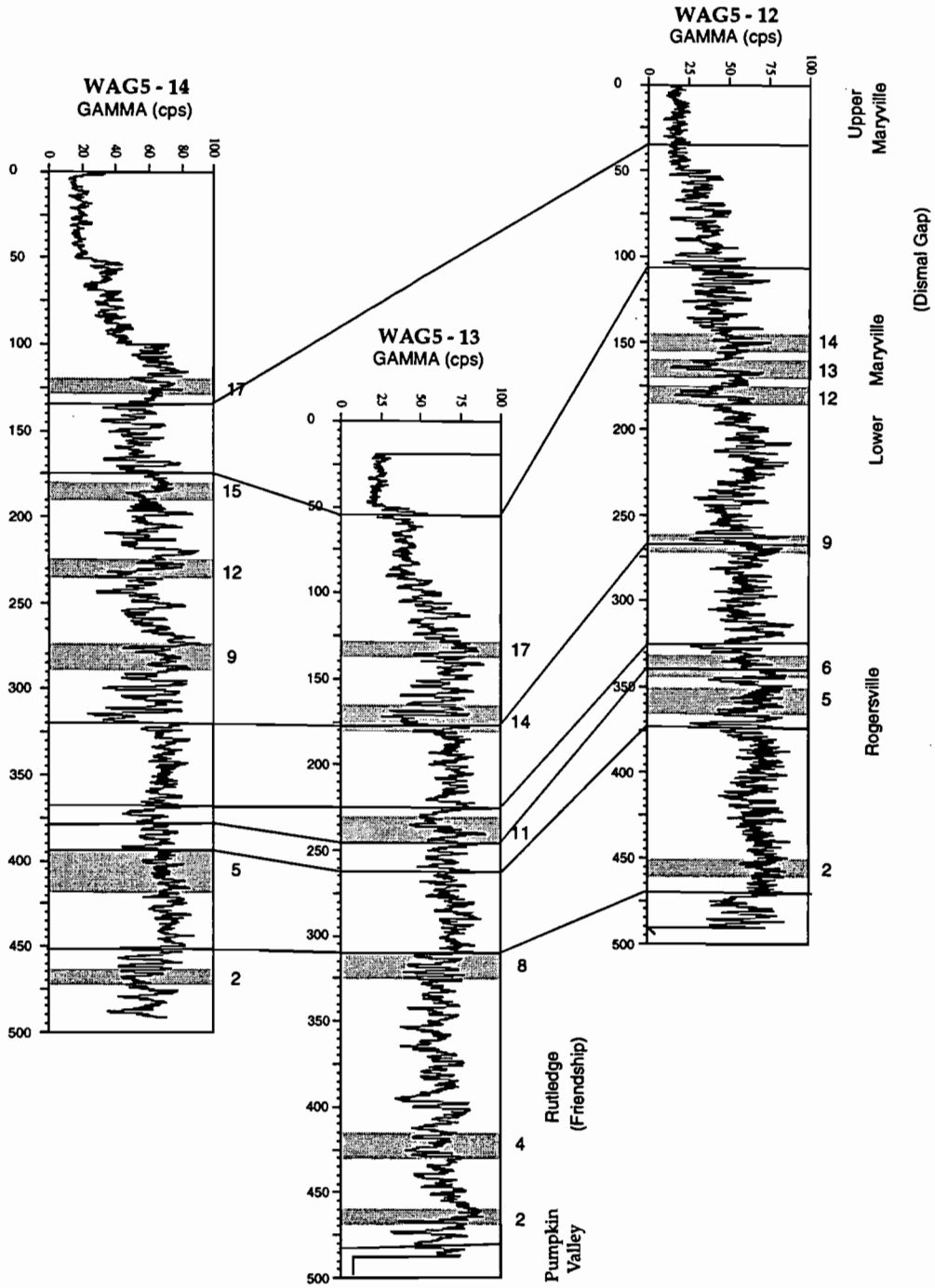

Fig. 2. WAG 5 stratigraphic correlation (BNI/Smith version). Sampling zones (by BNI, 1994) are illustrated by gray bars.

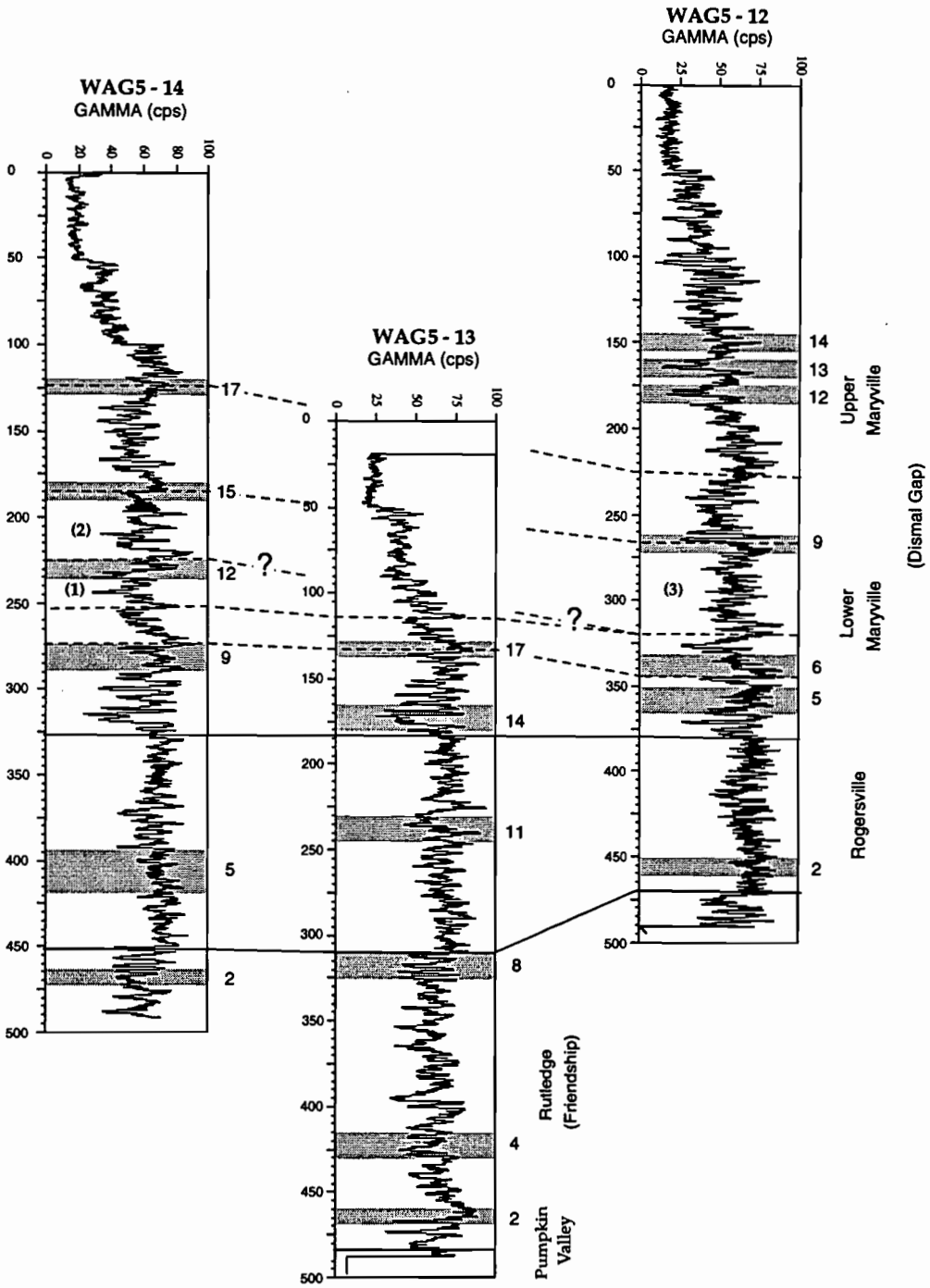

Fig. 3. WAG 5 stratigraphic correlation (new version). Sampling zones are shown by gray bars.

The primary difference between the two versions is in the thickness of the Rogersville Shale in WAG 5-12. The Rogersville Shale is easily recognized by a stable baseline. The lower contact with the Rutledge Limestone can be seen easily from the natural gamma log diagrams for each well. It is the same for both interpretations. But the upper contact between the Rogersville Shale and the Maryville Limestone for WAG 5-12 is different in the two versions: it is placed at the depth of 267 ft in the old version (Fig. 1) and at 380 ft in the new one (Fig. 2).

The reasons why we trust our correlation more than the previous one are as follows:

1. The old one does not match the type description. The lithology between 340 and 267 ft depth at the top of the formation is a gray to greenish gray shale. The type description of the Rogersville Shale shows a maroon shale for this interval (Table 5 listed in BNI et al., 1994).

2. The Rogersville Shale in the original version (Fig. 1) is thicker than any other Rogersville Shale observed in Melton Valley. Thicknesses of geologic units for Melton Valley and Bear Creek Valley (Hatcher et al., 1992) and for WAG 5 (both correlations) are given in Table 2.

3. The Rogersville Shale, according to the original version, contains a relatively large proportion of limestone. This is seen by the baseline shift toward higher cps within the shale bed on the gamma log diagram. Type descriptions of the Rogersville Shale do not include limestone (Hatcher, 1992).

We suggest that the baseline shift and changing baseline above 380 ft corresponds to the Maryville Limestone. The problem of our version is that all beds become thinner in the well WAG 5-12, but we still trust it more than the original version.

The bottom of the Rutledge Limestone (top of the Pumpkin Valley Shale) is observed only in WAG 5-13. It is the same for both versions. To check this contact, the natural gamma logs were compared with those of Bear Creek Valley and Melton Valley (Hatcher et al., 1992).

Some of the contacts on Fig. 3 are shown with a dashed line. These are informal contacts that occur within a formation, and they are not so certain as contacts between formations. Nevertheless, we feel confident with this correlation on a local scale. The informal contact between lower Maryville Limestone and upper Maryville Limestone is determined only for wells WAG 5-12 and WAG 5-14. For WAG 5-13, it is not available because the surface casing extends past the contact.

Table 2. Stratigraphic thickness*

	Crt	Crg			Cm lower	
Bear Creek Valley	92-125 105	69-118 102			134-161 148	
Melton Valley	102-148 125	85-157 118			154-279 200	
WAG5		WAG5-14	WAG5-13	WAG5-12	WAG5-14	WAG5-12
NEW	174	125	126	90	141	115
OLD	174	129	133	204	186	232

*Thickness of geologic units is given in feet. Thicknesses of units in Bear Creek Valley and Melton Valley are taken from Hatcher et al. (1992). Thickness is given as a range (X-X) and as an average. NEW = thickness according to new correlation (given in this report); OLD = thickness according to old correlation (BNI/Smith).

The correlation figure (Fig. 3) shows that the bed thickness is relatively constant from WAG5-14 to WAG5-13 but is thinner in WAG5-12. In addition, as shown by the dashed lines with "?" question marks, the package (1) possibly is structurally duplicated in WAG5-14. Alternatively it may just show similar thinning as in surrounding units.

3.2 SAMPLING ZONES

Sampling zones for WAG 5 multiport wells are presented in BNI et al. (1994) and are illustrated in Figs. 2 and 3 by a gray bar. Stratigraphic correlation of sampling zones in wells WAG5-12, WAG5-13, WAG5-14 is given in Table 3. In addition, sampling zones that occur at a similar depth (within 25 ft) are shown in Table 4. These tables help to put hydrologic data (such as water chemistry or fluid pressure) into a geologic context, particularly because the zones were chosen from hydrogeologic data.

Table 3. Sampling zone stratigraphic correlation*

Stratigraphic Unit	WAG5-12 Zone	WAG5-13 Zone	WAG5-14 Zone
Upper Maryville	14 13 12		17
Lower Maryville	9		17 15 12
	6	17	
	5	17	9
		14	
Rogersville	2	11	5
Rutledge		8 4 2	2

*Sampling zones are numbered consecutively from the base of the well. Sampling zones within the same stratigraphic unit are shown by gray bars.

Table 4. Sampling zones depth correlation*

Depth Range (ft)	WAG5-12 Zone	WAG5-13 Zone	WAG5-14 Zone
124-135		17	17
135-150	14	17	
165	13		
173-185	12	14	15
230-238		11	12
265-282	9		9
317-338	6	8	
360	5		
407-423		4	5
456-469	2	2	2

*Depth is given in feet below surface. Zones that occur within a 25-ft range are shown by gray bars.

3.3 GEOLOGIC CROSS SECTIONS

Geologic strike and dip were determined from three-point problem analysis. The contact Rogersville Shale–Maryville Limestone as observed in the three multiport wells in WAG 5 was accepted as a marker. For solving the problem, we generated an EXCEL spreadsheet and used the method described in Ragan (1973). Bed strike is approximately 95 degrees east with a dip 14 degrees to the south. But strike and dip can vary slightly for other marker beds because bed thickness varies between boreholes.

A strike perpendicular cross section A-A' (Fig. 4) was constructed through the well WAG 5-13. The line of section is shown in Fig. 1. Data from wells WAG 5-12 and WAG 5-14 were projected along strike into the section. Strata observed in wells WAG 5-13 and WAG 5-14 show a relatively constant thickness. In contrast, as discussed earlier, strata observed in well WAG 5-12 show substantial thinning, resulting in change in the value of dip at different formation contacts. Therefore, change between WAG 5-14 and WAG 5-12 shows geologic changes along strike. This cross section illustrates the problem of thickness change between WAG 5-14 and WAG 5-12 beds. As a result, the portion of the cross-section between WAG 5-12 and WAG 5-14 probably is not representative of the geology along the line of section. Based on it we can only say that a lot of changes along strike take place.

Implications:

1. Strike and dip calculations can only be approximate and strike may vary 5 to 10 degrees.

2. Data from WAG 5-12 should not be projected onto strike perpendicular cross-section.

Therefore, we constructed a second strike parallel cross section (Fig. 5) to illustrate thickness changes at a 1-to-1 scale. This cross section shows bed thinning from WAG 5-14 (grid-west) to WAG 5-12 (grid-east). Bed thinning in WAG 5-12 remains a problem in interpretation that may not be resolved. The suggestion is that the thickness change is an original sedimentary feature. Probably it is caused by the surface relief during the deposition. But for beds (1) and (2) within lower Maryville Limestone, thinning may be the result of subhorizontal thrust fault, which cuts through the well WAG 5-14 at an elevation of about 547 ft and through WAG 5-12 at an elevation of about 476 ft. In that case, we can suggest that section (1) has been repeated and (2) is the same bed as (1) (Figs. 3 and 5). Based on the gamma log diagrams (Fig. 3), this is the most likely location of a fault. Alternatively, the strata between a depth of 185 and 255 ft in WAG 5-14 corresponds to bed (3) in WAG 5-12 (Fig. 3). The relationship between beds (1), (2), and (3) (Figs. 3 and 5) is questionable and needs more study.

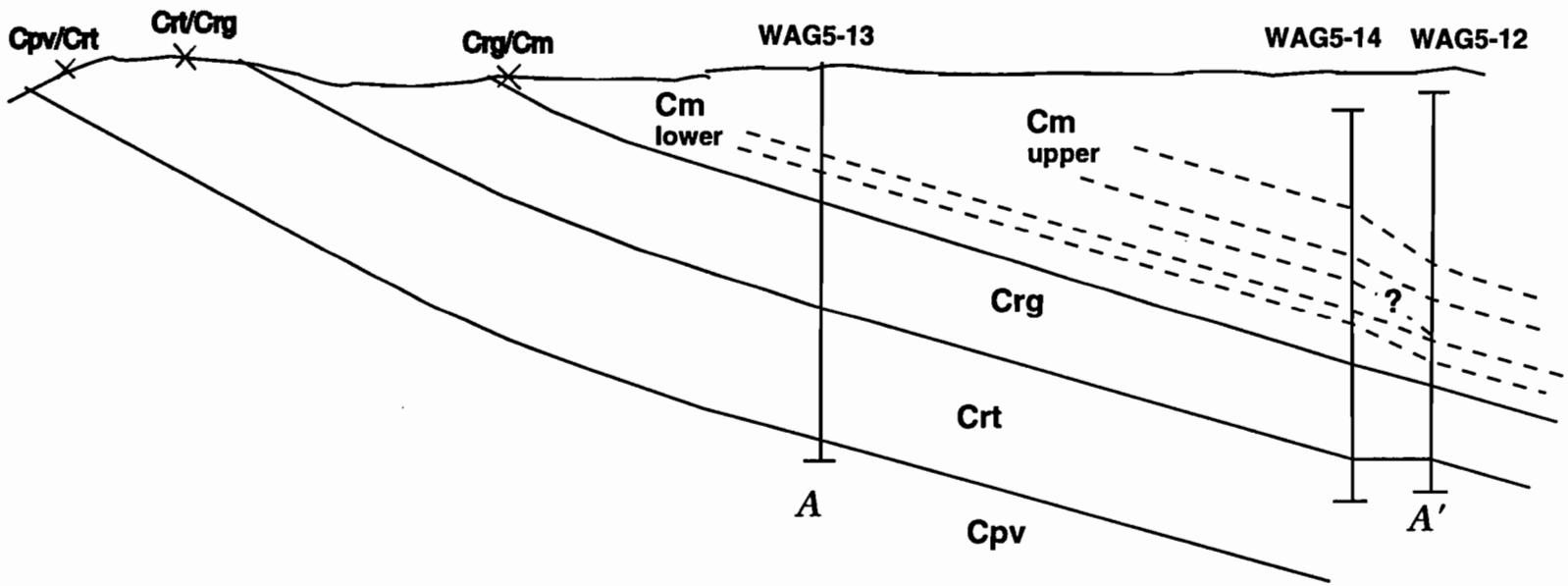

Fig. 4. Strike-perpendicular geologic cross section in WAG 5. Geologic contacts taken from Hatcher et al. (1992) are shown by ×.

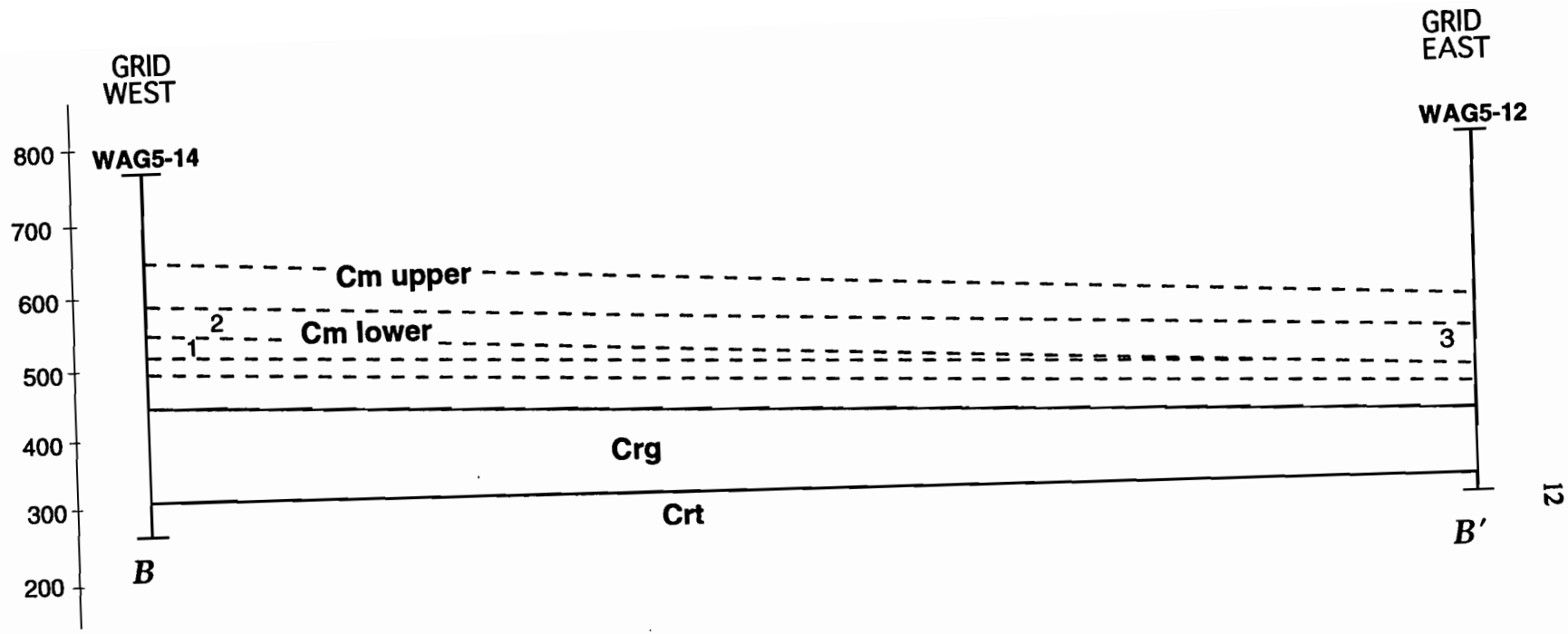

Fig. 5. Approximate strike-parallel geologic cross section in WAG 5.

3.4 GEOLOGIC MAPS

The geologic map of WAG 5, which is based on data presented in Hatcher et al. (1992), shows the Cpv–Crt, Crt–Crg, and Crg–Cm surface contacts in the northern part of WAG 5 (Fig. 1). The surface contacts were put on the cross section through wells WAG 5-12, WAG 5-13, and WAG 5-14 (Fig. 1). It shows a slight mismatch between subsurface and surface data. Surface contacts require a Rogersville Shale thickness increase and thickness decrease of the Rutledge Limestone. Because of the fact that (1) such a large increase and decrease requires a complicated geologic history and (2) it is difficult to perform both an increase and decrease in thickness by simply changing the dip, we prefer to interpret the situation the uncomplicated way (i.e., projecting of subsurface data to the surface with a minor change in the value of dip). Therefore, in order to make the thickness constant, the Rutledge Limestone–Rogersville Shale contact was moved about 70 ft south, the Pumpkin Valley Shale–Rutledge Limestone contact was moved about 50 ft north, and the Rogersville Shale–Maryville Limestone contact was moved about 30 ft north. The surface topography supports this interpretation: the hill (Fig. 4) is probably formed by the Rutledge Limestone, which is more resistant than the Rogersville Shale, and decrease of surface elevation corresponds to the Rogersville Shale.

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