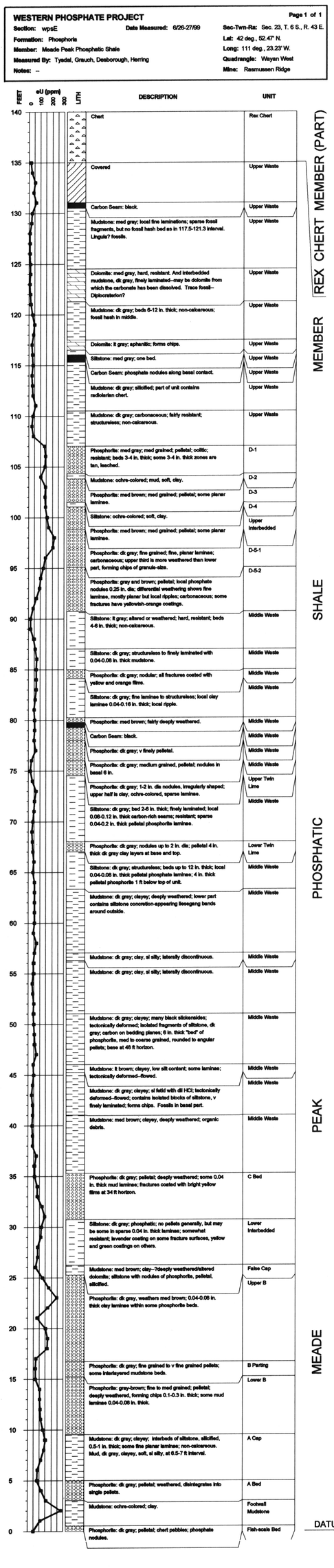
U.S. DEPARTMENT OF INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 99-20-C

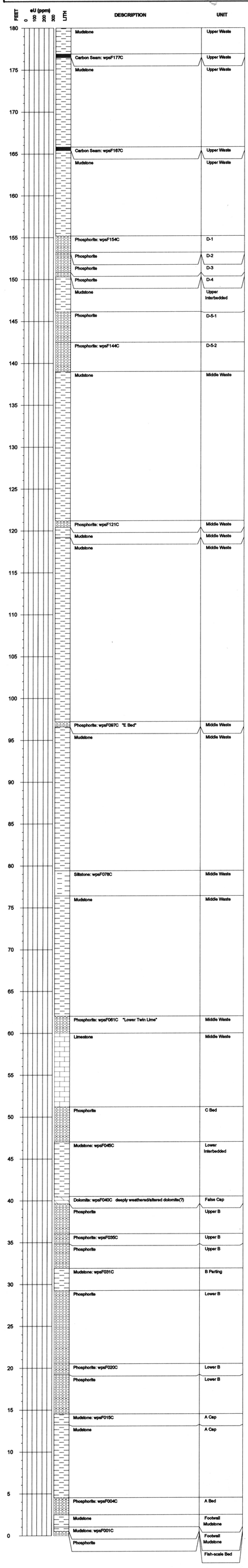
WESTERN PHOSPHATE PROJECT — Page 1 of 1

Section: wpsE — Date Measured: 6/26-27/99 — Sec-Twn-Rg: Sec. 23, T. 6 S., R. 43 E.
Formation: Phosphoria — Lat: 42 deg., 52.47' N.
Member: Meade Peak Phosphatic Shale — Long: 111 deg., 23.23' W.
Measured By: Tysdal, Grauch, Desborough, Herring — Quadrangle: Weyan West
Notes: -- — Mine: Rasmussen Ridge



WESTERN PHOSPHATE PROJECT — Page 1 of 1

Section: wpsF — Date Measured: 6/27/99 — Sec-Twn-Rg: Sec. 23, T. 6 S., R. 43 E.
Formation: Phosphoria — Lat: 42 deg., 52.74' N.
Member: Meade Peak Phosphatic Shale — Long: 111 deg., 23.15' W.
Measured By: Tysdal, Desborough, Grauch, Herring — Quadrangle: Weyan West
Notes: -- — Mine: Rasmussen Ridge



INTRODUCTION

The U.S. Geological Survey (USGS) has studied the Permian Phosphoria Formation in southeastern Idaho and the entire Western U.S. Phosphate Field throughout much of the twentieth century. In response to a request by the U.S. Bureau of Land Management, a new series of resource, geological, and geoenvironmental studies was undertaken by the USGS in 1998 To accomplish these studies, the USGS has formed cooperative research relationships with two Federal agencies, the Bureau of Land Management and the U.S. Forest Service, tasked with land management and resource conservation on public lands; and with five private companies currently leasing or developing phosphate resources in southeastern Idaho. The companies are Agrium U.S. Inc. (Rasmussen Ridge mine), FMC Corporation (Dry Valley mine), Rhodia Inc. (Wooley Valley mine—inactive), J.R. Simplot Company (Smoky Canyon mine), and Solutia Inc. (Enoch Valley mine). Some of the mineralogical research associated with this project is supported through a cooperative agreement with the Department of Geology and Geological Engineering, University of Idaho.

Present studies consist of integrated, multidisciplinary research directed toward (1) resource and reserve estimations of phosphate in selected 7.5-minute quadrangles; (2) elemental residence, mineralogical and petrochemical characteristics; (3) mobilization and reaction pathways, transport, and fate of potentially toxic elements associated with the occurrence, development, and societal use of phosphate; (4) geophysical signatures; and (5) improving the understanding of deposit origin. Because raw data acquired during the project will require time to interpret, the data are released in open-file reports for prompt availability to other workers. Open-file reports associated with this series of studies are submitted to each of the Federal and industry cooperators for technical review; however, the USGS is solely responsible for the data contained in the reports.

MEASURED SECTIONS

Stratigraphic sections of the Phosphoria Formation were measured and sampled by the USGS at several places in southeastern Idaho. The sections, generally lacking interpretation and explanatory notes, are published as preliminary reports as they are assembled. No thin section, X-ray, or analytical technique other than gamma-ray spectrometry has been used to augment the field descriptions of the rock units in this report. The descriptions are accompanied by a computer-generated lithologic log. General bed designation names--A, B (lower ore zone), C, D (upper ore zone)--introduced by Hale (1967, p. 152), and used generally throughout southeastern Idaho, are shown in the unit column. Subdivisions of these general names, also shown in the unit column, are the informal bed names used at the Rasmussen Ridge mine. Contacts of units within the ore zones were picked by mine personnel; those within the middle and upper waste zones generally were picked by USGS personnel. The units within the measured sections were sampled for geochemical and petrological analysis and also were evaluated with a variety of geophysical techniques. Sample numbers (for example, wpsF020C) are shown within measured section wpsF. English units of measurement are used throughout this report to facilitate direct correspondence with units in the extensive historical literature on the Phosphoria and with current industry usage.

The Phosphoria Formation in the vicinity of the measured sections consists of three members, which in ascending order are the Meade Peak Phosphatic Shale, the Rex Chert, and the informally named cherty shale (McKelvey and others, 1959; Rioux and others, 1975; Oberlindacher, 1990). The measured sections in this report focus on the Meade Peak Phosphatic Shale Member. The Meade Peak unconformably overlies the Grandeur Tongue of the Permian Park City Formation, and the cherty shale member is overlain by the Triassic Dinwoody Formation. Both sections were measured on surfaces exposed by mining equipment. Section wpsE (western phosphate section E) was measured along a horizontal surface; section wpsF was measured along a steeply inclined face. Section wpsE is located about 1,400 ft south of section wpsF and about 150 ft below the pre-mining land surface. Lower strata of section wpsF were measured about 25 ft below the pre-mining surface, upper strata about 40 ft below the surface. Rocks of section wpsF are intensely weathered and those of the much deeper section wpsE are extensively altered, probably because fluid pathways were provided by abundant fractures that resulted from fairly intense tectonic deformation. Prior to weathering, the rocks of section wpsF might have been altered chemically by subsurface fluids. Measuring a pair of sections close together, but at different depths below the pre-mining land surface, permits evaluation of important effects of weathering on rock geochemistry. Measurements record true thickness. Adjustments were made for dip of beds at the time of measurement of section wpsE, but the true thickness of units in section wpsF were calculated later from the apparent thicknesses measured on the outcrop. The section was measured soley to provide stratigraphic positioning of selected rock units that were sampled for chemical and mineralogical analysis. No detailed descriptions were made of the strata in the sections. Stratigraphic units of the middle waste, for example, are shown mainly as mudstone, although interbeds of other rock types also exist in the middle waste. Sample numbers shown in section wpsF represent channel samples taken across the entire thickness of the indicated interval. The two sections are of unlike thickness, chiefly because the middle waste zone of section wpsE has been thinned tectonically. Moreover, not all of section wpsF is well exposed and some strata of the middle waste might be repeated.

EQUIVALENT URANIUM (eU)

Section wpsE is accompanied by a profile of the equivalent uranium (eU) measurements taken with a GAD-6 gamma-ray spectrometer. No measurements were made in the deeply weathered section wpsF. The spectrometer measures gross gamma-ray flux (including cosmic rays) and provides a quantitative measure of K, U, and Th. Determination of the abundance of U and Th was obtained via detection and counting of gamma rays of specific energy associated with a particular daughter radionuclide for each element, ^{214}Bi with a 1.76 MeV (million electron volt) gamma-ray in the case of uranium. Calculation of total abundance of U and Th assumes secular equilibrium between the measured daughter nuclide and the parent isotope and all intermediate daughter nuclides for each individual element. Potassium abundance is determined from the measurement of gamma rays associated with the decay of ^{40}K. The spectrometer integrates detection over a 2π geometry of approximately 1/2 m^3 and has proportionally higher detection sensitivity to those gamma rays that are emitted closer to the detector. The calibration equations for the spectrometer assume this geometry on a planar surface and are based on analysis of concrete pads of known composition of the three elements. The calibration coefficients, as well as the constants for subtracted background counts, are a function of latitude, altitude, rock density, and moisture. The coefficients become less reliable as location and rock conditions change from those of the calibration.

In similar past studies, we plotted eU concentration data after normalization of the highest eU concentration (Tysdal and others, 1999) and as unscaled, raw concentration data (Tysdal and others, 2000). This latter report discusses the reasons for the original scaling and the decision to subsequently not scale eU concentrations. The data presented in this report use the same calibration equations as were used in the two prior reports, permitting direct comparisons with eU concentrations. A recalibration of the GAD-6 instrument in April, 2000, indicates that eU concentrations in the previous reports should be reduced by 18 percent. This reduction is exactly proportional, thus all concentrations should be reduced by the same percentage. Relative changes among all reported concentrations for a measured section are accurate as depicted.

Previous studies of the Phosphoria Formation state that there is a consistent relationship between eU and total uranium content and between total uranium and phosphate content (McKelvey, 1956). Our measurements indicate considerable scatter in both relationships (fig. 1; Herring and others, 1999; Herring and others, 2000; Herring, unpub. data). Measured eU concentrations, even between adjoining 1 foot intervals of consistent lithologic character, often exhibit considerable variability. We suspect that this results from (1) fine-scale variability in the concentration of uranium; (2) the effect of the geometry of the dipping rocks; or (3) a lack of secular equilibrium. Scatter in the U to P_2O_5 relationship results from uranium removal or addition by syndepositional effects and (or) by post-depositional alteration, especially weathering. The uranium is mostly located in the phosphate mineral lattice as a substitute for Ca; location of the decay (daughter) products is uncertain. For the phosphatic rocks of the Phosphoria Formation, total gamma counts are dominated by decay of uranium and its various daughter products. K_2O is generally <1 percent in the phosphorite and <3 percent in the middle waste shale; Th concentrations are generally <15 ppm (parts per million) in ore and waste shale (Altschuler and others, 1958; Swanson, 1970; Herring and others, 1999; Herring and others, 2000; Herring, unpub. data). The eU concentration is approximately equivalent to that of the total uranium; both concentrations are given in ppm.

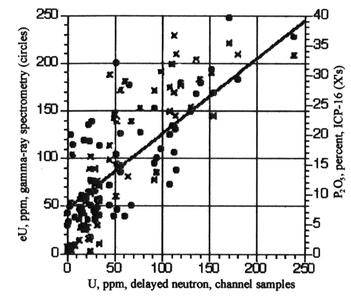


Figure 1. Comparison of measured uranium concentration by delayed neutron analysis in channel samples with gamma-ray spectroscopy measurements taken at 1-foot true-thickness stations through the same intervals and arithmetically averaged (circles). The least-squares regression (R^2 = 0.55) line is shown. Concentrations of P_2O_5 in percent are shown for the same samples (x's).

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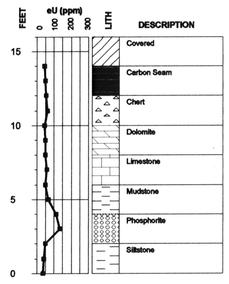
ACKNOWLEDGMENTS

The sections were measured within the Rasmussen Ridge mine, operated by Agrium Inc. We thank Agrium for providing access, and we thank company personnel who freely discussed the geology of the area.

EXPLANATION

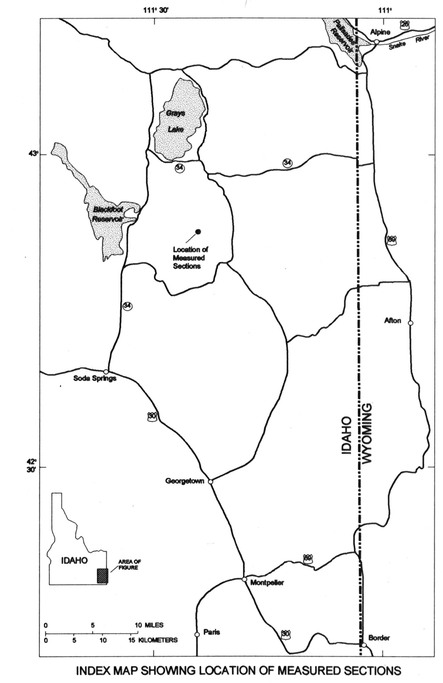


ABBREVIATIONS

dia	diameter
dil	dilute
dk	dark
eU	equivalent uranium
ft	feet
in.	inches
lith	lithology
med	medium
ppm	parts per million
sl	slightly
v	very

CONVERSIONS

Some thin layers within the stratigraphic sections originally were measured in millimeters, then converted to English units. A thickness of 1 millimeter converts to 0.04 inches, implying a measurement precision greater than actually exists.



INDEX MAP SHOWING LOCATION OF MEASURED SECTIONS

Prepared in Collaboration With:

U.S. Bureau of Land Management
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R. Simplot Company
Monsanto Co.
Rhodia Inc.

STRATIGRAPHIC SECTIONS AND EQUIVALENT URANIUM (eU), MEADE PEAK PHOSPHATIC SHALE MEMBER OF PERMIAN PHOSPHORIA FORMATION, EAST-CENTRAL PART OF RASMUSSEN RIDGE, CARIBOU COUNTY, IDAHO

BY

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2000