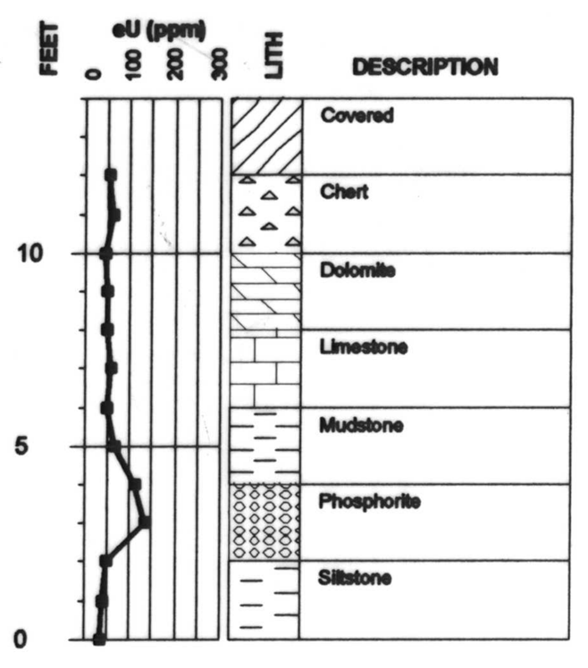
U.S. DEPARTMENT OF INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 99-20-D

EXPLANATION

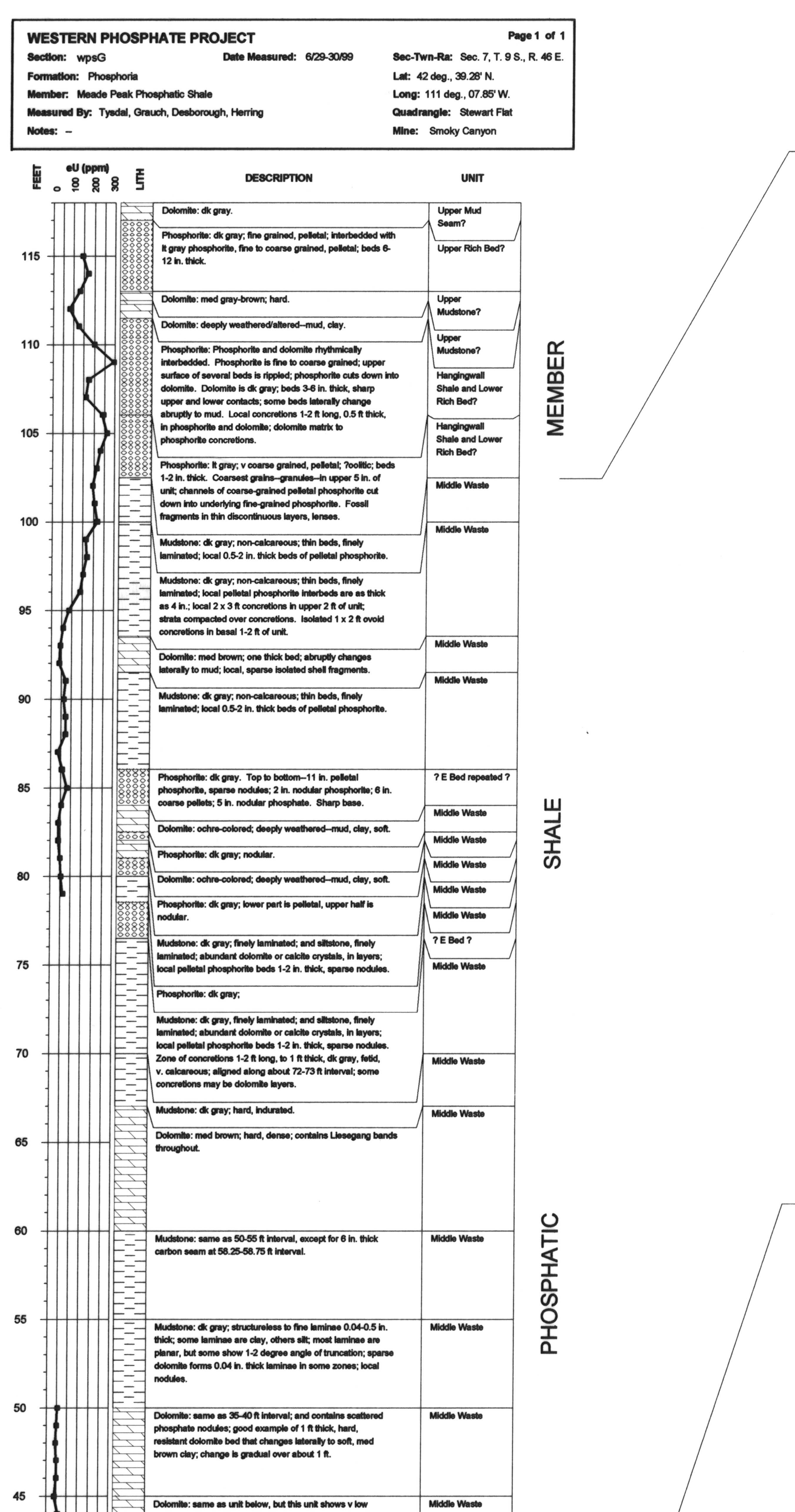


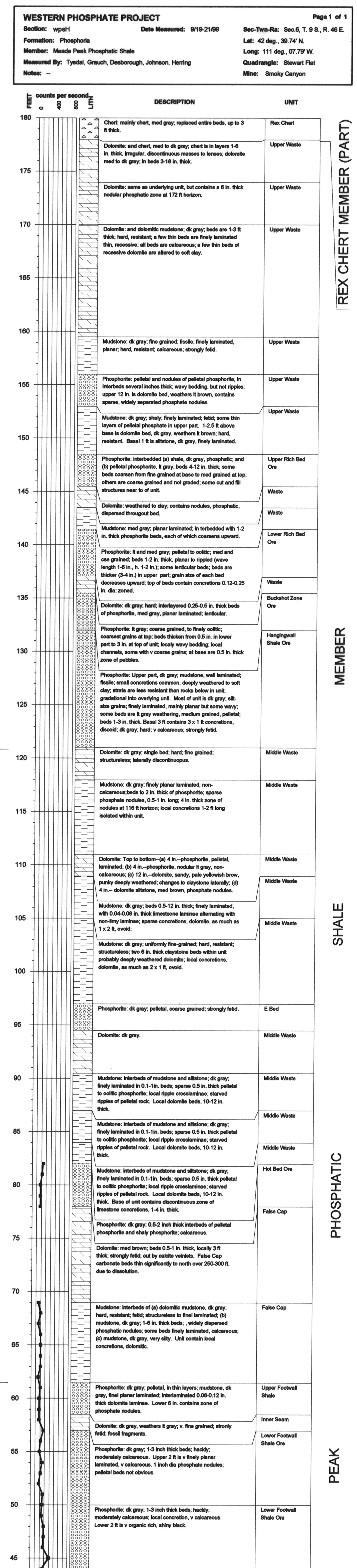
ABBREVIATIONS

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.





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. Informal bed names (for example, upper footwall shale ore) used at the Smoky Canyon mine are shown in the unit column. The more general unit names (A, B, C, D) applied to these strata in southeastern Idaho by Hale (1967, p. 152) are not shown in the unit column. The units within the measured sections were sampled for geochemical and petrological analysis and also were evaluated with a variety of geophysical techniques. 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; Montgomery and Cheney, 1967; Brittenham, 1976). The measured sections of 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 wpsG (western phosphate section G) is about 3,000 ft south of section wpsH. The lower 1/3 of section wpsG was measured along a horizontal surface, the upper 2/3 along a steeply inclined pit-wall flanking a cut bench about 25 ft higher than the lower half of the section. Uppermost strata of the Mead Peak Phosphatic Shale Member were not exposed at the section wpsG measurement site. Section wpsH was measured along a steeply inclined pit-wall, gradually stepping upward across three 40 ft high benches from the base to the top of the section. 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. The depth below the pre-mining surface of section wpsG ranges from about 175 ft for the lower part of the section to about 150 ft for the upper part. Depth below the pre-mining surface of section wpsH ranges from about 50 ft for the lower strata to about 150 ft for upper strata. Measurements record true thickness. Adjustments were made for dip of beds at the time of measurement.

Strata in the vicinity of the two measured sections dip 20-30 degrees westward, on the back limb of a major anticline. Both sections are cut by local low-angle faults, of unknown displacement, that dip slightly less than to slightly greater than the dip of bedding. These faults caused repetition of strata in some areas, but many caused omission of strata. One such low-angle fault zone cuts through section wpsG and caused omission of the upper two units of the lower ore zone (Hot Bed and Phosphatic Shale, which combined total 7-10 ft thick) and about 25 ft of the lowermost strata of the middle waste (near 35 ft interval, section wpsG). Middle waste strata between the "? E Bed repeated ?" (near 85 ft interval, section wpsG) and the upper ore zone of the section are thinner than normal, suggesting omission of strata by an unrecognized fault. In section wpsH, the Cap Rock units between the lower two lines of correlation (6.5-62 ft interval) are much too thick for a normal sequence in this area. The mudstone strata between the two phosphorite sequences of these lower strata contains a thickened, poorly exposed zone that is interpreted to host a low-angle thrust fault. The fault is about parallel to bedding, and served to repeat nearly the entire lower ore zone, although the fish-scale bed is not repeated.

EQUIVALENT URANIUM (eU)

Measured section wpsG is accompanied by a profile of the equivalent uranium (eU) measurements taken with a GAD-6 gamma-ray spectrometer. No spectrometry measurements were made in the deeper (below former ground surface) altered section wpsH, although some gamma scintillometry measurements are included across two parts at and near the base of the section. 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 occurs 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, 2000a and 2000b). The reasons for the original scaling and the decision to subsequently not scale eU concentrations are discussed in Tysdal (2000a). 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 this and 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.

For section wpsG, the interval from 35-50 feet was measured on the lower bench, which offered a flat, horizontal surface, rather than continuing measurements at 35 feet along with the stratigraphically described and sampled section on the next higher bench, with its flanking vertical face. This interval is possibly thickened by a low-angle fault and may not correlate directly with the same footage interval on the next higher bench. Within the interval from 51-78 ft, spectromety measurements were made on the lower bench from 51-68 ft, and values were typical of middle waste rock. However, these values are not included because of location uncertainties within this apparently faulted sequence.

Total gamma counts per second as measured across the energy detection spectrum of the spectrometer, approximately 1.5 to 2.6 MeV, correlate with eU with $R^2 > 0.99$. This indicates that uranium produces most of the measured radioactivity and that the contribution to measured radioactivity from potassium and thorium is small. Consequently, the gross gamma counts measured by a scintillometer also will correlate fairly well with uranium content and, secondarily, with phosphate content. In a previous measurements, section wpsE (Tysdal and others, 2000a), the correlation between counts per second on the spectrometer and a scintillometer (Mount Sopris Instrument Company, Model SC-132) was $R^2 = 0.82$. For section wpsH the scintillometer used was a Geometrics GR101A, which has a smaller detector crystal that the one used for section wpsE. Consequently, the absolute count rate for samples of section wpsH is notably less than that of section wpsE. Nonetheless, the scintillometry measurements of section wpsH are internally consistent from one to another and can be related in relative magnitude to the spectrometry and scintillometry scans of other sections.

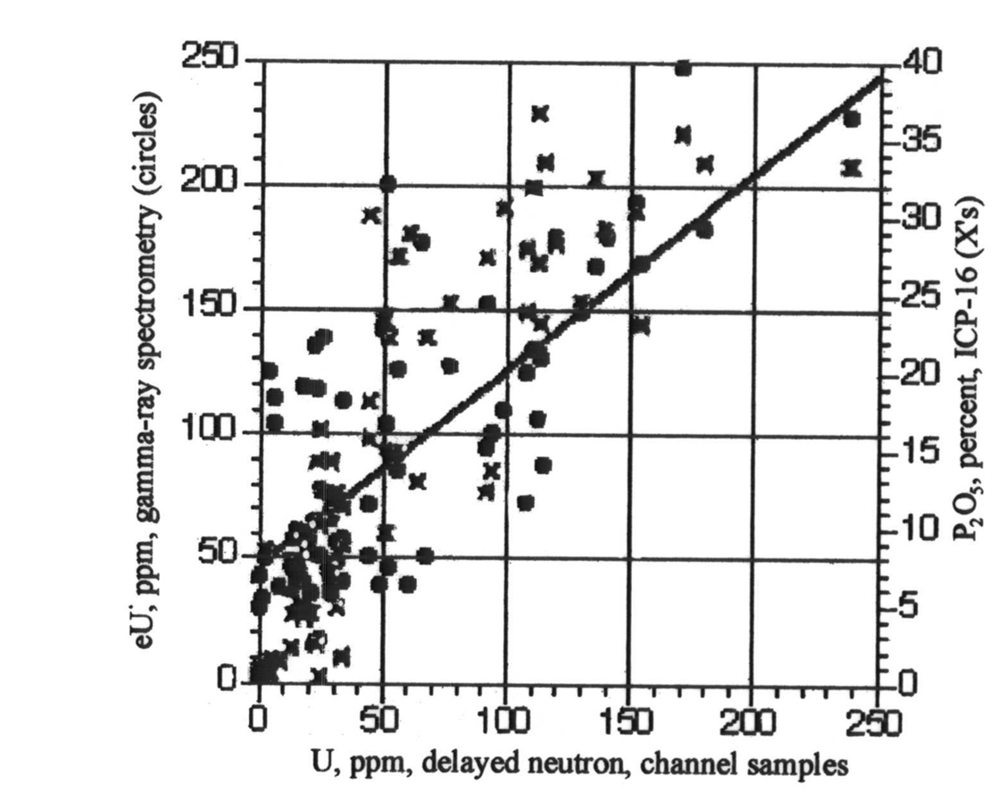


Figure 1. Comparison of measured uranium concentration by delayed neutron analysis in channel samples with gamma-ray spectroscopy measurements taken at 1-foot true-thickness stations through the same intervals and arithmetically averaged (circles). The least-squares regression ($R^2 = 0.55$) line is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

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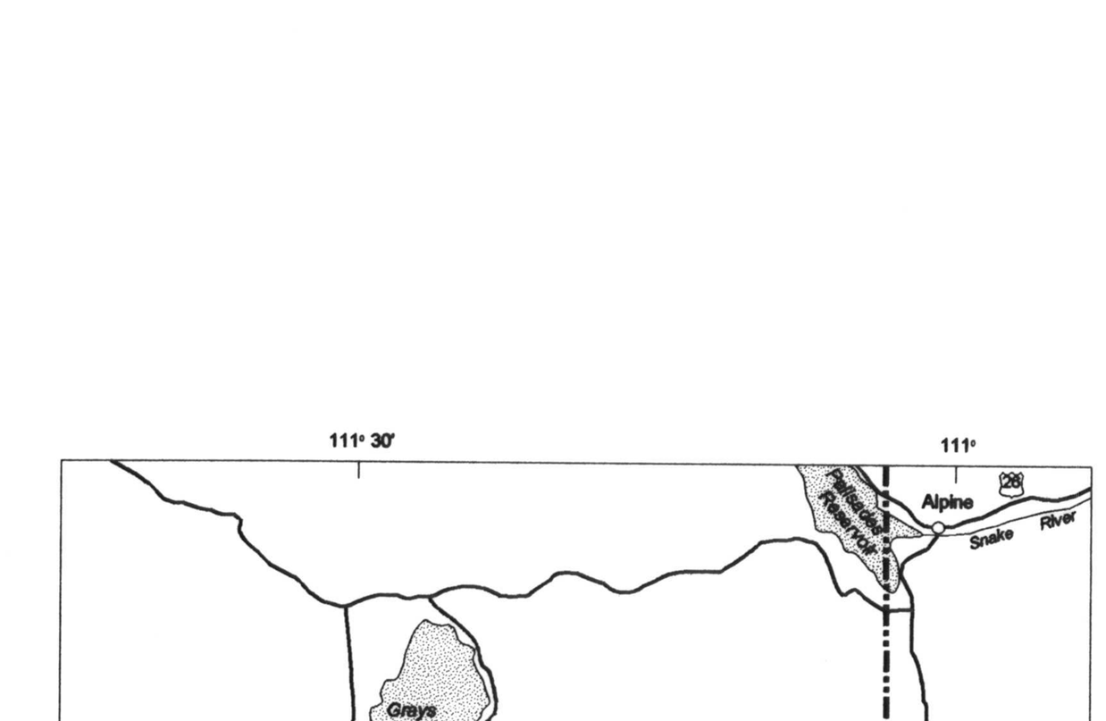
ACKNOWLEDGMENTS

The sections were measured within the Smoky Canyon mine, operated by the J.R. Simplot Company. We thank the J.R. Simplot Company for providing access and we thank company personnel who freely discussed the geology of the area.



INDEX MAP SHOWING LOCATION OF MEASURED SECTIONS

Prepared in Collaboration With:
U.S. Bureau of Land Management
U.S. Forest Service
Agrium U.S. Inc.
Astaris LLC
J.R. Simplot Company
Monsanto Co.
Rhodia Inc.

STRATIGRAPHIC SECTIONS AND EQUIVALENT URANIUM (eU), MEADE PEAK PHOSPHATIC SHALE MEMBER OF PERMIAN PHOSPHORIA FORMATION, SAGE CREEK AREA OF WEBSTER RANGE, CARIBOU COUNTY, IDAHO

BY
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2000