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Kwarteng, Andrews Mensah Yaw, D.G.S.

The University of Texas at El Paso, 1988

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REMOTE SENSING APPLIED TO THE EXPLORATION FOR URANIUM-MINERALIZED BRECCIA PIPES IN NORTHWESTERN ARIZONA

by

ANDREWS MENSAH YAW KWARTENG, B.Sc., M.Sc.

DISSERTATION

Presented to the Faculty of the Graduate School of

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in Partial Fulfillment

of the Requirements

for the Degree of

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REMOTE SENSING APPLIED TO THE EXPLORATION FOR URANIUM-MINERALIZED BRECCIA PIPES IN NORTHWESTERN ARIZONA

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To my wife, Dora,

our three lovely girls,

Juanita, Francine, Afua,

and to all who believe in

" brighten your corner wherever you are and wherever you come from "

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"Me da Nyame ase;
Yen nananom ne Agonafoo
nsamanfoo nyinaa, me da
mo ase a ensa da."

ABSTRACT

The currently depressed uranium market makes high-grade uranium deposits the only economically viable and attractive exploration target. In the United States, exploration for uranium-mineralized breccia pipes in northwestern Arizona is active because of the high-grade ore they contain which can also include such by-products as Ag, Au, Cu, Pb, Zn and V. These breccia pipes were formed from the collapse of the overlying sedimentary strata into karst caverns developed in the Mississippian Redwall Limestone. Mineralization of the breccia pipes occurred between 200 and 220 m.y. ago as determined by U-Pb isotopic analyses.

Field and laboratory spectroscopic studies using Landsat Thematic Mapper (TM) band-passes clearly demonstrate that the surfaces of breccia pipes were indistinguishable from their immediately surrounding areas. The hydrothermal event accompanying the uranium-mineralization introduced new clays into the pipes. These clays were found to be indistinguishable from the ubiquitous diagenetic clays in sediments in the study areas, using TM bands. Discriminant analysis of the field, laboratory, and Landsat TM digital numbers indicates that 64-80% of the samples collected on the surfaces of breccia pipes and their immediately surrounding areas were correctly classified; however, the classification data from some previously known breccia pipes were not encouraging.

Digital image processing techniques were applied to Landsat TM, color infrared photograph (NHAP), and airborne geophysical data of selected areas in northwestern Arizona to evaluate the utility of the remotely sensed data in breccia pipe exploration. The color composites of selected enhanced TM bands, printed at the scale of 1:100,000, resulted in the recognition of some of the previously known orebodies as well as several anomalies in the study areas. The criteria utilized were

the appearance of circular features and the size of known breccia pipes. Enhancement of a digitized NHAP photograph improved appearance of circular and other structural features in comparison with the unenhanced NHAP and a color aerial photograph. Digital image processing techniques applied to the geophysical data sets included: (1) conversion of the data into gridded grey-scale images, (2) spatial filtering for noise removal, (3) integration and analysis of the data sets, and (4) modeling using various parameter combinations. One of the most promising models developed in this study incorporated apparent resistivity and total field magnetics. The results of this model outlined 13 anomalies representing 12% of the survey area. The processing and critical analysis of the geophysical data is apparently the most promising approach to breccia pipe exploration in this study.

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CHAPTER 1

INTRODUCTION

The primary goal of this study was to examine how digital image processing techniques applied to remotely sensed data comprised of (1) Landsat Thematic Mapper (TM), (2) airborne geophysics, and (3) an infrared color photograph, could potentially contribute to exploration for mineralized breccia pipes in northwestern Arizona. The geophysical data consisted of apparent resistivity, total field magnetics, overburden thickness, and very low-frequency electromagnetics (VLF-EM). The color infrared photograph was collected as part of the National High Altitude Photography (NHAP) program, coordinated by the U.S. Geological Survey. Digital analysis of the Landsat TM, geophysical and NHAP data was performed using the U.S. Geological Survey's Mini Image Processing System (MIPS) at Flagstaff, Arizona. Two sites in northwestern Arizona, approximately 2100 sq km each, were selected as the study areas for this research.

1.1 Breccia Pipes in Northwestern Arizona

Orebodies developed exclusively in brecciated rock have received and are still receiving much attention from both research and exploration geologists. The reasons are twofold: first, the intrinsic scientific interest associated with their genesis, and second, the relatively high-grade ore they often contain. Some of the significant deposits found in brecciated rock worldwide include: lead and zinc from the Mississippi Valley type deposits, copper-molybdenum in porphyry copper systems, and precious metals in epithermal deposits. The majority of such orebodies developed in brecciated rock are found in igneous rocks; however, significant

numbers are developed in sedimentary and metamorphic rocks.

A mineralized breccia pipe is a cylindrically shaped, more or less vertical orebody containing brecciated rock. A breccia pipe may or may not be mineralized. In this context and subsequent chapters, the usage of breccia pipe is limited to a mineralized pipe unless stated otherwise. Breccia pipes in northwestern Arizona are formed in sedimentary rocks, and are unrelated to any volcanic or intrusive activity. They were formed from the collapse of the overlying sedimentary strata into solution caverns developed in the Redwall Limestone (Bowles, 1965; Gornitz and Kerr, 1970; Wenrich, 1985). Mineralization of the breccia pipes occurred within the interval 200-220 m.y. as determined by U-Pb isotopic analysis (Ludwig et al., 1986). In theory, all areas on the Colorado Plateau underlain by the Redwall Limestone are permissive for the occurrence of mineralized breccia pipe deposits.

Mining for metals in the Grand Canyon area commenced in the 19th Century, and since then U, Cu, Pb, Zn, Au, and Ag have been mined from many deposits (Pierce et al., 1970). Some of the deposits were later recognized as breccia pipes. The main commodity exploited from the breccia pipes has changed from Cu to U since the 1950s. Figure 1 shows the location of past mines, current mines, possible orebodies, and identified breccia pipe mineral occurrences in northwestern Arizona. More than 20 orebodies have been discovered since the late 1970s. At present (1988) there are 2 active mines and 4 others are scheduled to start mining operations soon. Many more breccia pipes and suspected pipes have been mapped by Huntoon et al. (1981 and 1982) on the Grand Canyon and adjacent regions, but mining and prospecting in national parks and forests are prohibited by Federal law. An ongoing U.S. Geological Survey breccia pipe exploration program has identified several collapse features on the Hualapai Indian Reservation that may possess the potential

FIG. 1. Index map of northwestern Arizona showing the major structural units, the study areas and breccia pipes. Numbers refer to the following breccia pipe names: (1) Grand Gulch, (2) Savannic, (3) Cunningham, (4) Snyder, (5) Old Bonnie Tunnel, (6) Copper House, (7) Copper Mountain, (8) Parashant*, (9) Chapel*, (10) Ridenour*, (11) Mohawk, (12) Sage, (13) Platinum, (14) Lynx, (15) Rose, (16) SBF, (17) Orphan*, (18) Grandview*, (19) Canyon, (20) New Year, (21) Black Box, (22) Otto, (23) Riverview*, (24) Arizona, (25) Pinenut, (26) Hack 1, (27) Hack 2 & 3, (28) Rim, (29) Kanab South, (30) Kanab North, (31) Pigeon, (32) Hermit, (33) DB, (34) What, (35) EZ-1, (36) EZ-4, (37) EZ-2, (38) Lisa, (39) John, (40) Peace.

* old mines (developed before 1980) from which uranium was mined.