DETAILED GRAVITY AND MAGNETIC SURVEY OF THE
TAYLORSVILLE TRIASSIC BASIN

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Introduction

Continental rift basins around the world contain about 5% of the earth's sedimentary layers and produce about 20% of the total hydrocarbon production of the world (Ziegler (1983). Nearly 30 large basins of this type are reported by Manspeizer and Cousminer (1988) in eastern North America and northwestern Africa. There are eleven exposed basins of this type in the state of Virginia, from which nine are totally and two partially within the state's border. The number of unexposed basins is not known. Exploration and drilling have been hampered largely because surface data are insufficient for even evaluation of those basins, which are partly or completely exposed in the Piedmont Province. Generation of data through random exploratory drilling and seismic exploration is much too expensive and, therefore, these methods have not been widely used. In order to remedy this situation, we have used a geophysical method and completed a detailed and dense ground gravity surveys of the Richmond (Nowroozi and Wong, 1989, Daniels and Nowroozi, 1987). In this work we report our progress on collecting existing gravity data in a rectangular area covering the Richmond and Taylorsville Basins and its vicinity. The area covers one-degree latitude and one degree longitude, starting at 37 North, 77 West and ending at 38 North, 78 West. Dr. David Daniels of the United State Geological Survey supplied us with more than 4900 Bouguer gravity anomalies in this area. The purpose of this report is to present the data in form of several maps and discuss its relation to the geology of the Triassic Basins and its vicinity. Johnson and others (1985) also presented a map of the Bouguer gravity anomaly of this area. However, their map covers a smaller area, and it is based on smaller number of observations.

Important Geological Features of the Area

Surface Geology of this area is compiled by The United State Geological Survey and the Commonwealth of Virginia, Department of Mines, Minerals, and Energy, 1993. Figure 1 presents the geology of the study area. The Richmond and Taylorsville Basins are north, northeast trending faulted structures that contain Late Triassic clastic rocks (Johnson and others, 1985). These basins are two of many elongated faulted basins of early Mesozoic age, which are mapped along the eastern coast of North America from Nova Scotia to Georgia. All the basins are aligned with the Appalachian structural trend. The Richmond basin is about 12 miles west of the City of Richmond, the Basin is about 33 miles long and has a maximum width of ten miles, its total area is about 260 square miles (Weems, 1980). The Taylorsville basin is about 16 miles north of the city of Richmond. It has an exposed

length of 12 miles and a width of seven miles; its approximate exposed area is 50 square miles; however, its unexposed area is not known, (Weems, 1980). The Bouguer gravity anomaly helps in defining the unexposed area of this basin.

Mainly igneous and metamorphic rocks bound the Richmond basin; the Petersburg granite and a thin veneer of Tertiary sediments bound the central and northern segment of the eastern border of this basin. The granite is generally associated with a negative Bouguer gravity anomaly. The southern segment of the eastern border and a section of the southern and western border are bounded by undifferentiated mica gneiss. The central and northwestern border is limited by Goochland complex. This consists of State Farm gneiss, Sabot amphibolite, and Maidens gneiss (Farrar, 1984). The exposed section of the Taylorsville basin is bounded by the Petersburg granite on the south, cataclastic rocks on the west, and Coastal Plain sediments on the east. The Taylorsville basin may extend under the sediments along its east-northeast trend. Also, there are a few intrusive diabase dikes in the basins, which are formed probably during the original rifting.

Hylas Fault

In this area the sedimentary units of the Late Triassic eastern belt generally dip toward west bounded by the major normal or listric Hylas fault zone which forms the western boundary of both basins. The Hylas fault zone has a complex history of movements (Bobyarchick and Glover, 1979). The fault is exposed in vicinity of the town of Hylas, it moves northeastward and defines the western boundary of the Taylorsville basin and moves southwestward to form the western boundary of the Richmond basin. The fault zone is composed of mylonitized granite gneiss, biotite gneiss, and amphibolite with a linear northeast trend. This trend is associated with a very strong gravity gradient and is the dominant geophysical feature of the basins. The Hylas Fault is marked by a well-defined narrow zone of Bouguer gravity anomaly. The variation in the gravity anomaly across this band may be as much as 20 mgals. Nowroozi and Wong (1989) showed that the Bouguer gravity anomaly of the fault is consistent with a listric or a normal fault motion.

Geology of the Richmond and Taylorsville Triassic Basins

Geology of the Richmond and Taylorsville basins is discussed by a number of authors (Bobyarchick and Glover, 1979; Weems, 1980; Goodwin, 1982; Johnson and others, 1985; Nowroozi and Wong, 1989, Milici and others, 1991). Sedimentary rocks consists of conglomerate, arkosic sandstone and siltstone deposited in a fluvial environment. Lenses of lacustrine limestone and shale, as well as coal beds are also present, Figure 2.

Stratigraphy of the Taylorsville Basin is similar to that of Newark Supergroup, Doswell Formation, and Newfound Member; at this basin it consists of siltstone- conglomerate facies, sandstone and shale, and sandstone and conglomerate. Stratigraphy of Richmond is also similar to that of Newark Supergroup; at this basin it consists of Otterdale sandstone, Vinita bed shale and sandstone, and Tuckahoe group coal measures, shale, sandstone, and coal. The last unit consists of boulder and conglomerate beds, gneiss, granite and mylonite (Johnson and others, 1985).

Map of the Bouguer gravity Anomaly

We requested the available data gravity from the United State Geological Survey. Dr. David Daniels provided us with over 4900 observations from the files of Defense Mapping Agency (DMA), and National Ocean and Atmospheric Administration (NOAA) files. The observation points have an identification index, latitude, longitude, elevation, observed gravity value, theoretical value, terrain correction, free air correction and a complete Bouguer correction. The individual references are too many to cite; however, the major contributors are Johnson and others (1985), Daniels and Nowroozi (1987) and, Nowroozi and Wong (1989). We have used the Surfer Program to construct the Bouguer gravity anomaly map (Figure 3).

The contour interval for the Bouguer gravity map is 1 milligal (mgal). The anomaly varies from - 23 mgals to + 30 mgals. Superposition of the Bouguer anomaly with the regional geology of the Triassic and basins and vicinity, and geology of the Richmond and Taylorsville basins are presented in Figure 4 and 5 respectively. Association of the Bouguer gravity gradient with the Hylas fault is clearly indicated. The gradient trend defines the northwestern boundary of both basins; this anomaly may be interpreted in term of a listric or normal fault motion, Nowroozi and Wong(1989). The southeastern boundary is not clearly marked. New gravity models are in progress.

Conclusions

1. Our work has extended the boundaries and final horizontal expression of the Taylorsville Basin (see Figure 5). More detailed work needs to be done to further define the boundaries of the basin in the vertical dimension.

We focused mainly on the Taylorsville Basin since this was the subject of our study. As a result this investigation did not reveal anything specifically new about the Richmond Basin. However, for a detailed investigation on Richmond basin see Nowroozi and Wong (1989).

2. The value of overlaying the Surface Geological Map with the Gravity Map

In order to establish the usefulness of the gravity data in locating new basins in the study area we overlaid the surface geologic map with the Simple Bouguer Gravity map in an effort to establish correlation between the observed gravity anomalies and the surface geology (Figure 4). Even though one would not expect a direct correlation between the surface geology and the gravity, it is reasonable that the surface could provide clues and information related to the subsurface geology that could affect the gravity.

When the two maps are superposed, several observations are apparent. We observe that there is a good correlation between surface geology and the gravity data. There seem to be several well-defined linear regions of contrasting gravity intensity and anomalies. Strong negative anomalies seem to correspond to linear geologic trends mainly underlain by granites. It is also very clear that the gradient changes and becomes very high in the areas where the boundaries of Triassic basins are located. This strong contrast in gradient is associated with density differences in the crustal rocks in the region and reflects boundary faulting associated with the basins' evolution. Nowroozi and Wong (1989) showed that the Bouguer gravity anomaly is consistent with listeric normal fault motion. The strong gradient change delineates the Hylas fault system, which defines the northwestern boundary of the Triassic basins in the study area. In looking for undiscovered Triassic basins with the gravity data, one would look along the linear region of high gravity gradient, which marks the controlling normal fault system. The linear region of high gradient is approximately 5 miles wide. It is in these areas that new basins are likely to be discovered (see Figures 4 and 5).

3. We improved the basin definition in several key areas (see Figure 5). First it was established more clearly that the northwestern and western sides of these basins is bounded by the Hylas fault system. Since the steep gravity gradient trend defines the Hylas fault system we have better information on the geometry of the western boundary faults. We also improved the overall definition of the Taylorsville basin and further delineated its near surface geologic structure.

Our work discovered a small basin west of Yellow Tavern but this area is probably an extension of the Richmond and Taylorsville basin complex when the area was a trough.

4. Evidence of other Unexposed Basins

This Investigation did not find any evidence for unexposed basins in the study area. The present Bouguer gravity map shows some negative gravity anomalies but these are probably related to granite intrusions into the metamorphic country rock.

5. Hydrocarbon Potential of the Taylorsville Basin

We conclude that the sedimentary, geothermal, and maturation history of the Taylorsville basin is such that there is very little chance of finding commercial quantities of gas reserves. Some methane has been generated in association with the conversion of plants to lignite and coal. However, no commercial quantities of gas with heavy hydrocarbon content should be expected in the area. The geothermal gradient is too low for gas and the thermal-maturation history is such that oil would be the dominant hydrocarbon phase in the area. There has been some oil production from sediments in the Taylorsville and other Triassic basins, but to date no commercial quantities of oil have been found. However, we do feel that there is the potential for exploration to establish commercial oil production in some of these basins.

Ziegler (1983) has studied the hydrocarbon potential of the Triassic - Jurassic rift basins of North America and has documented source rocks, migration potential routes, reservoir rocks, and trapping characteristics. His analysis suggested that the deeply buried lacustrine shale facies within the basins are rich in total organic carbon (TOC). For example he determined about 25% TOC in some layers of the Late Triassic Vinita beds which have a thickness of about 720 meters in the Richmond Basin. Such high TOC values are presumed to be true indicators of adequate source rock in this region. Five test wells have been drilled in the Richmond Basin which have recovered oil and a number of other wells drilled had oil and gas shows (Ziegler 1983).

The main factor that weighs against finding commercial quantities of oil in these basins is the fact that there is a lack of really good reservoir rocks. Even though there are thick sections of sandstones, limestones, conglomerates, siltstones, and other sedimentary rocks present, the predominance of the sediments are shales, siltstones and arkosic sandstones which don't make ideal reservoir rocks as they tend to have low effective porosities and permeabilities.

In spite of the negative aspects we feel that at this stage the Taylorsville, Richmond and other basins along this trend are essentially unexplored and probably contain thick sedimentary sections at depth. There is a great probability that detailed petroleum exploration in the future could lead to commercial oil production.

6. Areas that warrant further investigation:

a.) Further work needs to be done to determine the boundaries and geometry of the basins in the vertical dimension.

The following types of maps need to be made to help understand the basin deep geometry and geologic structure.

Residual Maps
First derivative Maps
Second derivative Maps

- b.) Further petroleum exploration should take place in the area. Structure, Stratigraphic, geochemical and other detailed subsurface studies should be made to further evaluate petroleum potential of these basins.
- c.) Areas to the north and along strike with known basins in our study area should be studied for new undiscovered basins. The gravity expression of the Hylas Fault system should be used as a guide in finding new basins.

Acknowledgments

We thank the Department of Energy for supporting this project and David Daniels, United State Geological Survey for providing the gravity data .

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Equipment Purchases and Related Expenses

The following computer equipment was purchased and donated to the Department of Geology at Elizabeth City State University to enable the students to accomplish their component of research.

Two Gateway Pentium Computers (E3000-1200 w/MMX Technology)
Computers have 3.2 GB hard drives and an Ensoniq Audio Kit.

Total Cost of the two computers = \$5000.00

During the course of this investigation we used Old Dominion University's gravimeter and magnetometers. Since Old Dominion magnetometer was old and had started to fail towards the end of this project we purchased a new proton-gradient magnetometer for the university. The instrument was purchased from Gisco Geophysical and Geophysical Instrument and Supply Company.

The cost of magnetometer = \$5769.00

Figure 1. Geological map of the Richmond and Taylorsville Triassic and Vicinity. Based on Geologic map of Virginia, Department of Mines Minerals and Energy and United State Geological Survey, 1993.

Geology of the Richmond and Taylorsville Triassic Basins

Figure 2. Geology of the Richmond and Taylorsville Triassic Basin (modified from Johnson and others (1985))

Figure 3. Simple Bouguer gravity anomaly map of the Richmond and Taylorsville Basins

Figure 4. Superposition of simple Bouguer gravity anomaly map and Geology map

Yukon Territory

Mt. Kinross

Legend

	100m contour interval		1:50,000 scale
	200m contour interval		1:25,000 scale
	500m contour interval		1:12,500 scale
	1000m contour interval		1:6,250 scale
	2000m contour interval		1:3,125 scale
	4000m contour interval		1:1,562 scale
	8000m contour interval		1:781 scale
	16000m contour interval		1:390 scale
	32000m contour interval		1:195 scale
	64000m contour interval		1:97 scale
	128000m contour interval		1:48 scale
	256000m contour interval		1:24 scale
	512000m contour interval		1:12 scale
	1024000m contour interval		1:6 scale
	2048000m contour interval		1:3 scale
	4096000m contour interval		1:1 scale
	8192000m contour interval		1:0 scale
	16384000m contour interval		1:0 scale
	32768000m contour interval		1:0 scale
	65536000m contour interval		1:0 scale
	131072000m contour interval		1:0 scale
	262144000m contour interval		1:0 scale
	524288000m contour interval		1:0 scale
	1048576000m contour interval		1:0 scale
	2097152000m contour interval		1:0 scale
	4194304000m contour interval		1:0 scale
	8388608000m contour interval		1:0 scale
	16777216000m contour interval		1:0 scale
	33554432000m contour interval		1:0 scale
	67108864000m contour interval		1:0 scale
	134217728000m contour interval		1:0 scale
	268435456000m contour interval		1:0 scale
	536870912000m contour interval		1:0 scale
	1073741824000m contour interval		1:0 scale
	2147483648000m contour interval		1:0 scale
	4294967296000m contour interval		1:0 scale
	8589934592000m contour interval		1:0 scale
	17179869184000m contour interval		1:0 scale
	34359738368000m contour interval		1:0 scale
	68719476736000m contour interval		1:0 scale
	137438953472000m contour interval		1:0 scale
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	1099511627776000m contour interval		1:0 scale
	2199023255552000m contour interval		1:0 scale
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	8796093022208000m contour interval		1:0 scale
	17592186044416000m contour interval		1:0 scale
	35184372088832000m contour interval		1:0 scale
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	140737488355328000m contour interval</		

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