Gravitational Subsurface Mapping of the City of Nacogdoches, Nacogdoches County, Texas

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Abstract

The city of Nacogdoches is located within Nacogdoches County in east Texas. According to the United States Census Bureau as of the 2010 census the city had a population of 32,996. More recently to the east of Nacogdoches, there have been reports of earthquakes and the possibility of these being caused in part due to the fracking of wells or if older faults may have become reactivated. Data retrieved from the United States Geological Survey indicates two possible known faults terminate within the study area. Approximately 20 miles to the north of Nacogdoches lies the Mount Enterprise Fault System. To the east of Nacogdoches, Texas is an additional normal fault system that is currently unnamed and is mapped to terminate approximately one mile from Loop 224 that surrounds the city of Nacogdoches. The study area lies between the salt domes of the East Texas Basin and those found in the Gulf Coast Basin, as well as salt cored structures found in the Trawick Field as well as to the east of the study area. Although hydrocarbon production, as well as seismic data, has been performed within the area, most of the data is proprietary and is not released to the general public.

This study utilized gravimetric analysis to characterize the subsurface within the city of Nacogdoches as well as a distance of 2.5 miles outside of Loop 224. Gravimetric surveying is a geophysical method of investigating subsurface features based on differences in densities found in the subsurface strata. This study was carried out using a gravimeter, an instrument that determines variations in the gravitational attraction over the surface of the Earth. A total of 660 stations, including the base station, were measured, using the Scintrex CG-5 Autograv Gravimeter. Locations were determined to be along major roads with a spacing of one-quarter to one-third miles apart using ArcMap 10.6. Geographical coordinates were determined for each of the stations and confirmed in the field using a Trimble NOMAD GPS equipped with a Trimble Pathfinder and Trimble Tornado. A digital elevation model was created from collected LiDAR data and provided elevation values for each of the stations. The elevation values were used for elevation corrections, free-air, and Bouguer correction, which is a vital aspect of gravity correction in the creation of a Bouguer Anomaly map. The Bouguer anomaly map reveals lateral variations within densities of rocks within the subsurface. Well logs were acquired from the Railroad Commission of Texas, the Petroleum Data Library, as well as third-party sources and analyzed using Petra Software to build cross-sections of the area to determine subsurface thicknesses, as well as depths to major formations, as well as any to provide general locations of faulting.

This study will lead to a better understanding of the local subsurface geology found within Nacogdoches, Texas.

Methodology

Using ArcMap 10.6 a total of 660 measurement locations were placed along known roads throughout the study area (Figure 5). The locations were spaced to be between one quarter and one-third miles apart from one another. The Scintrex CG-5 Gravimeter (Figure 6) was used to collect field data, along with a Trimble Nomad, Pathfinder Pro XH, and Tornado were used to confirm GPS accuracy (Figure 7). The Scintrex CG-5 Gravimeter was programmed to allowed for a 10-second delay before taking readings every 30-seconds for five minutes. Data collected from the field was then entered into Microsoft Excel to allow for corrections to be made.

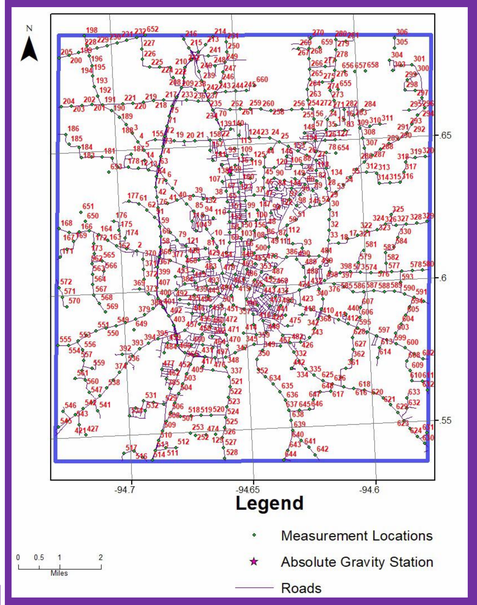

Figure 5

Figure 6

Figure 7

Corrections

These corrections were used when processing the measured data as recommended by Dornfeld (2012),, Okocha (2017) and Minteer (2018).

• Free-Air Anomaly:

FAA = Residual Gravity (mGal)+(0.3086*height (m))

•Latitude Correction:

Lat=Sin(2λ)*0.812 [mGal]

•Drift Correction:

Drift=$(B_2-B_1)/(T_2-T_1)$ [mGal/min]

•Theoretical Gravity (1987):

TG= $978032.68\left(\frac{1+0.0019311853\sin^2(\varphi)}{\sqrt{1-0.0066943799013\sin^2(\varphi)}}\right)$ mGal

•Atmospheric Loading:

g_a=(ΔP [mbar]*(-0.42)) [μGal/mbar]

•Residual Base Station Correction:

RB= Bn-B1 [mGal]

Simple Bouguer Anomaly:

BA=Residual Gravity+((0.3086-(0.04193ρ))*h[m]

Location

• The study area lies within Nacogdoches County, Texas and surrounds the city of Nacogdoches, extending approximately 2.5 miles from Loop 224 in all directions (Figure 1). Surficial deposits consist of predominantly Eocene aged sand, clay or mud with streaks of Holocene sand/silt, Eocene sandstone, clay or mud, Eocene sandstone/siltstone and Pleistocene and Holocene terrace, sand (Figure 2)

• The city of Nacogdoches lies within the Gulf Coast Coal Region as well as the Tx-LA-MS Salt belt, to the southeast of the East Texas Basin, southwest of the North Louisiana Salt Basin and north of the Gulf Coast Mesozoic and western Gulf Shelf (Figure 3).

• Although no known salt structures exist within the study area; two areas are in close proximity with known salt formations. (Figure 4).

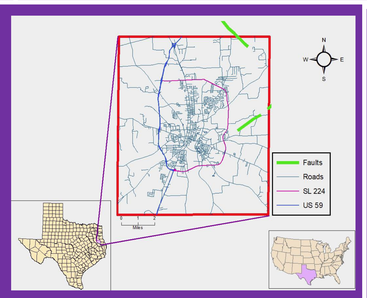

Figure 1

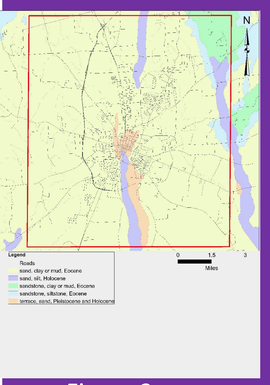

Figure 2

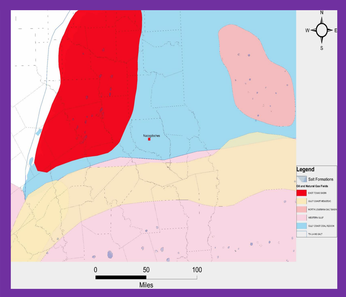

Figure 3

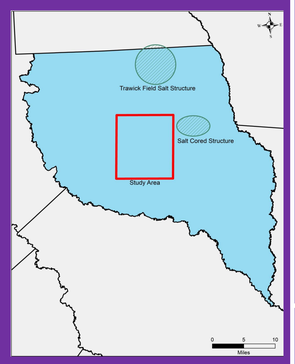

Figure 4

Results

Using Golden Surfer 7 the data was then plotted to show any trends that may occur. The theoretical gravity (Figure 8) illustrates what was to be expected of the area with high gravity values being found within the northern section of the study area and then slowly decreasing the further south. The observed gravity (Figure 9) was determined by taking the measured gravity and subtracting the drift, latitude, atmospheric pressure and residual base station corrections from that and correlating the data to a location that the absolute gravity had been measured. The residual gravity anomaly map (Figure 10) was created by taking the theoretical gravity and subtracting the observed corrected gravity. This illustration as well as the Free-Air Anomaly illustration (Figure 11) further support this theory. The areas of which low or high values come up on either side may be in fact due to creekology as well as anthropogenic affects. The Bouguer Anomaly Map (Figure 12), also indicates that gravity does decrease as moving south through the study area, approximately mid range there is a sudden drop in gravity. This may be in part due to a thinning of subsurface strata, a termination of an aquifer, or other features.

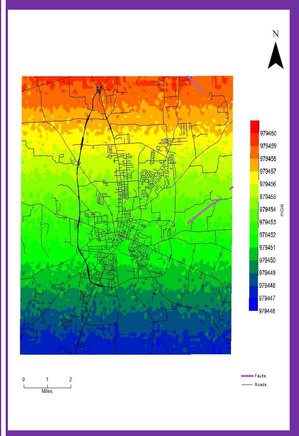

Figure 8
Theoretical Gravity map

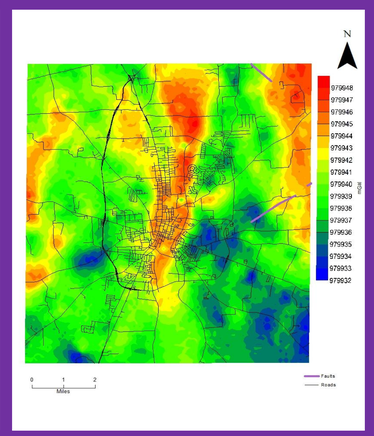

Figure 9
Observed Gravity map

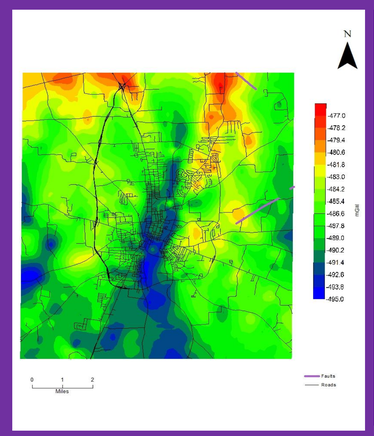

Figure 10
Residual Gravity map

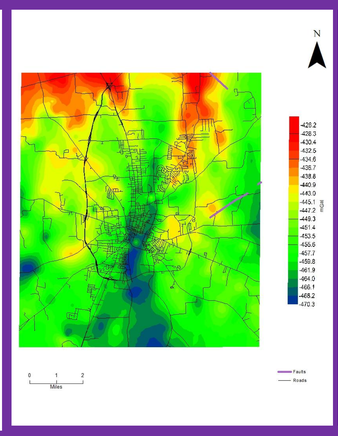

Figure 11
Free-Air Anomaly Gravity map

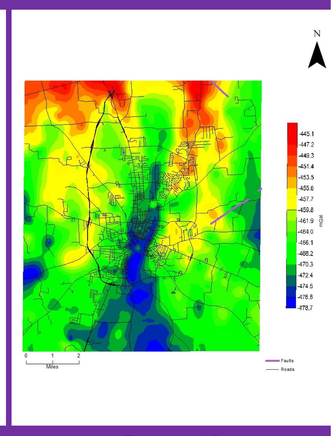

Figure 12
Simple Bouguer Anomaly Gravity map

Results

Dornfeld, W.A., 2012, Basement Control as the Origins of the Mount Enterprise Fault System (MEFS) a Possible Degassing Mechanism for the Haynesville Shale, Rusk County, Texas [Thesis].

Minteer, D., 2018, A Geophysical Delineation of a Normal Fault Within the Gulf Coastal Plain, Montgomery County, Texas [Thesis].

Okocha, F., 2017, Gravitational Study of the Hastings Salt Dome and Associated Faults in Brazoria and Galveston Counties, Texas [Thesis].