Republic of Ghana

BUILDING

A NATURAL CAPITAL ACCOUNTING SYSTEM FOR GHANA

ASSET ACCOUNTS
FOR MINERAL RESOURCES IN GHANA
(2006-2014)

UNDER THE
NATURAL RESOURCES AND ENVIRONMENTAL GOVERNANCE
(NREG) TECHNICAL ASSISTANCE PROGRAMMME

DECEMBER 2016

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List of Acronyms

AA	Asset Accounts
AGA	AngloGold Ashanti
AGF	Abosso Gold Fields
ARL	Adamus Resources Ltd
CML	Chirano Gold Mines Ltd
GBC	Ghana Bauxite Company
GCD	Ghana Consolidated Diamonds
GCM	Ghana Chamber of Mines
GDP	Gross Domestic Product
GFGL	Gold Fields Ghana Limited
GMC	Ghana Manganese Company
GSR	Golden Star Resource
GSR	Golden Star Resources
MC	Minerals Commission
NGGL	Newmont Ghana Gold Ltd
PMGL	Perseus Mining Ghana Ltd
PMMC	Precious Minerals Marketing Company
PS	Prestea Sankofa

1.   Introduction

Minerals are natural solid inorganic or natural solid fossilized organic materials such as base and precious metals, coal and other industrial materials found on the earth's crust measured in form, quantity, grade that has reasonable prospects for extraction (MMG Limited, 2014; Chartered Institute of Marketing, 2010; Mondal, 2015).

Mineral resources compared to other natural resources are unique in that they are initially unknown, fixed in size and location, variable in quality which creates both problems and opportunities; reserves are dynamic, in that volatile world prices and technological changes determine the feasibility and profitability of extracting the ore reserve; involve operations that have significant impact on the environment; non-renewable, in that once extracted, it will take a very long time to replenish raising issues of sustainability. These, among other, makes investments in mineral resources very risky.

Many mineral resources such as gold, diamond, manganese, bauxite, copper, phosphate, nickel, chromium, uranium, barite, basalt, clay, dolomite, feldspar, granite, gravel, gypsum, iron ores, kaolin, laterite, limestone, manganese, marble, mica, phosphate, phosphorus, rocks, salts, sands, sandstones and slates can be found in Ghana. Of all these minerals, the most important in terms of economic importance and export earnings are gold, diamond, manganese and bauxite with gold contributing over 90 percent of all mineral export earnings.

According to the Ghana Export Promotion Council (2010), bauxite was discovered in Ghana in 1914 and exploration and mining works began in the 1940s by the Ghana Bauxite Company (GBC). There are also substantial reserves of bauxite in Nyinahin and Kibi (Mensah, 2014). Manganese mining in Ghana started in 1916 by American- owned African Manganese Company until 1975 when production was taken over by the government under the management of National Manganese Corporation. The Ghana Consolidated Diamonds (GCD) used to produce diamonds on a large scale but the company ceased production when efforts to privatize the company did not succeed. Since the 1990s, diamonds are being produced on small scale bases mostly by indigenes in the Birim River in the Akwatia township and its environs.

Gold is categorized into quartz vein, disseminated sulphides, tockwork and alluvial gold mineralization. Gold deposits are found in the Ashanti belt, Kibi-Winneba belt, Sefwi-Bibiani belt, Bui belt, Bole-Nangodi belt, Wa-Lawra belt, Kumasi basin (Asankrangwa belt), Sunyani basin and the Maluwe basin (Minerals Commission, 2015). Gold mining companies in Ghana are mainly classified into two main group; namely Large-Scale Mining (LSM) and Small-Scale Mining (SSM) companies. Two types of SSM can be

identified- officially registered SSM and the illegal SSM popularly known as 'Galamsey'[1], though they are all classified as one in many situations. Even though information on the size of illegal SSM is readily not available, guestimates by the MC and the PMMC indicates that less than 30% of SSM are registered and the sector currently employs about a million Ghanaians. This implies that majority of SSM are not registered, operating as informal entities, largely not compliant with any law, disorganized and pose considerable health, safety and environmental risks. Twerefou *et al*. (2013) estimate with data from MC that out of the 10,521.30 km^2 of land under various concessions[2] in 2013, only 1.72 percent has been allocated to SSM.

Even though the size of land allocated to SSM is not that large compared to that of the LSM, their production and direct and indirect employment creation is relatively significant and has increased over the years. Specifically, gold production by SSM was about 3% of total national gold production in 1990 but has increased to about 36 % in 2014. The output of SSM are bought mainly by Precious Minerals Marketing Company (PMMC) and Asap Vasa established in 2013.

Large Scale Mining companies are officially registered companies mostly owned by foreigners with the government having a 10% stake which could be increased to about 20% as required by Law. Between 2006 and 2014, about 13 LSM Gold mining companies have been operating in Ghana. These are Gold Fields Ghana Limited (GFGL) – Tarkwa, Gold Fields Ghana Limited (GFG) – Damang, AngloGold Ashanti (AGA) – Obuasi, AngloGold Ashanti (AGA) – Bibiani, AngloGold Ashanti (AGA) – Iduapriem, Golden Star Resources (GSR) - Bogoso/Prestea, Golden Star Resources (GSR) – Wassa, Chirano Gold Mines Limited (CGML), Newmont Ghana Gold (NGL) - Ahafo, Central African Gold (CAG), Adamus Resource Limited (ARL), Persus, and Newmont Ghana Gold (NGL) - Akyem. (Minerals Commission, 2015; Ghana Chamber of Mines, 2016).

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[1] Means 'gather them and sell'
[2] These include Mining Leases, Prospecting License, Reconnaissance License and Small-Scale License

2. Conceptual Framework

2.1 Scope and Coverage

Even though several minerals can be found in Ghana, the asset account is limited to metallic minerals characterized by opacity, ductility and conductivity. These include gold, diamond, bauxite and manganese. The reasons for focusing on these four minerals is that, they are the most important minerals in terms of foreign exchange earnings, employment and contribution to GDP. Also, there exit some data on reserves, production, cost and revenue required for the accounting. There is also a central institution –MC which provides a one stop shop for all activities related to these minerals. The accounts also take into consideration only activities of the LSM due largely to the fact that there is little information on reserves and cost of SSM.

2.2 Framework for Asset Account

The methodology for the calculation of mineral Asset Accounts (AA) is based on the SEEA framework. The AA framework is made up of the Physical Account (PA) and the Monetary Account (MA). Specifically, the AA in the mineral accounting shows the opening and closing stocks and changes in the volume of mineral reserves and new discoveries in physical and monetary terms. It is designed to provide information on the stock level of minerals within the accounting years as well as activities that change stock levels which include minerals extracted, new discoveries, non-economic decisions such as mine closure, etc. The framework for the mineral AA is presented in Table 2.1.

Table 2.1: Structure of Asset Accounts for Mineral Resources

Physical Accounts (MT)	
Opening Stocks (OS)	**X**
- Extraction (Extraction) (E)	X
Other Accumulations (OA) (Changes due to Economic Decisions): + New Discoveries +/- Reassessment	 X X
+/- Other Volume Changes (OVC) (Other changes due to non-Economic Decisions)	X
Revaluation (monetary accounts only) (CS - (OS - Ext +/- OA +/- OVC)	
= Closing Stocks (CS)	**X**

From Table 2.1, AA account for minerals deals with stock level at the beginning of the accounting year (2006). **O***pening stock* which serves as the initial stock for the country to which new additions in the form of discoveries are made. The volume of minerals extracted is then deducted from the opening stock. Within the accounting year the mineral deposits can be reassessed to conform to international standards or changes in commodity prices in the global market or based on technological advancement in the exploration or there can be new discoveries. The ***new discoveries and reassessment*** therefore form the other accumulation. There is the possibility that certain proportions of the total volume of minerals mined within an accounting year will not be sold and these portions of the extracted minerals constitute the ***changes in stock***. The ***other volume changes*** constitute activities that are not economical to the mining companies such as perpetual closure and relinquishment of mining sites due to environmental, social and illegal considerations. Proper computation of the opening stock, extraction, other accumulations and other volume changes gives the ***closing stock*** at the end of the accounting year which becomes the opening stock for the following year. The revaluation is then ascertained.

3 Operationalizing the Framework

3.1 Source of Data

Available, unbiased, accurate and reliable data are needed to prepare Asset A for minerals. Data is required for the computation of opening stock, extraction, other accumulations, other volume changes, revaluation and closing stock, cost and revenue, among others.

Figure 3.1: Regional Geology Map of Ghana (Scale 1: 1,000,000)
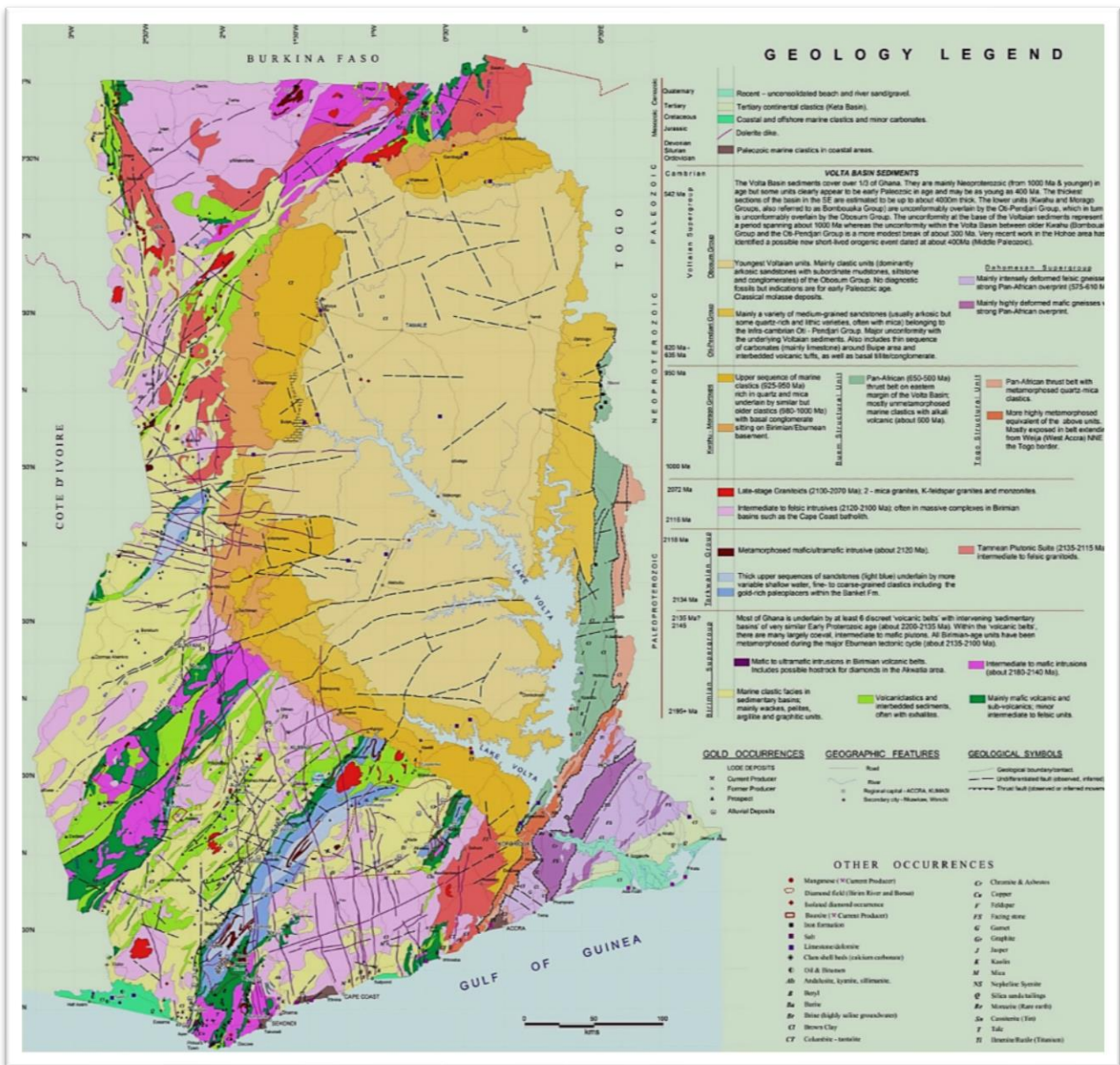
Source: Minerals Commission, 2015

Accurate information on mineral reserves in Ghana is very difficult to obtain. A survey done by the British Colonial government provided the ore deposits in Ghana (Figure 3.1). However, the Colonial Government did not go further to access the size and quality of the reserves. Since then, not much has been done overtly to obtain the accurate size and proven reserves of minerals in the country.

A Study by OpenOil (2012) and Federal Research Division (1995) provided some information on proven reserves and open reserves respectively for all minerals in Ghana. These formed the source of information on some mineral reserves.

The MC collects information from the LSM on their mineral resources disaggregated into inferred[3], indicated[4], measured[5] and the ore reserves disaggregated into proven[6] and probable[7]. After a thorough discussion with geologists at the MC and participants at a workshop organized by the Environment Protection Agency (EPA), it was agreed that probable and proven reserves should be used because of their geological certainty. Information on annual extraction (production) of the minerals under consideration were provided by MC. No information on the other volume changes regarding diamond, bauxite, manganese and gold were available for the compilation of the Asset Accounts (AA).

1.2   Estimation Methodology

We compile AA for gold, diamond, manganese and bauxite for the period 2006 to 2014 in both physical and monetary accounts. In physical terms, the AA is presented in both ore form and in metal content for gold, in ore form for bauxite and manganese and in metal form for diamond. No physical asset account in both ore and metal form was compiled for total minerals as it is deemed to be more appropriate to compile the physical asset account by type of mineral considering that each mineral has its own peculiarity. In developing the monetary accounts, two methods of valuation were employed t**he Net Price Method (NPM) and the El Serafy or User Cost Method (UCM).**

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[3] **Inferred Mineral Resource:** Mineral Resource for which tonnage, grade and mineral content has been estimated with a low level of confidence, inferred from geological evidence and assumed but not established geological and/or grade continuity.

[4] **Indicated Mineral Resource:** Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content has been estimated with a reasonable level of confidence based on exploration, sampling and testing information gathered through appropriate techniques

[5] **Measured Mineral Resource:** Mineral Resource for which tonnage, density, shape, physical characteristics, grade and mineral content has been estimated with a high level of confidence based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques

[6] **Proven Ore Reserve:** Economically mineable part of a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined determined through appropriate assessments and studies.

[7] **Probable Ore Reserve:** Economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined determined through appropriate assessments and studies.

3.2.1 Physical Asset Account

Physical accounts for the minerals deal with stock level at the beginning of the accounting year (2006), additions in the form of new discoveries, extractions (depletion), other volume changes, and stock at the close of the accounting year.

Reliable estimates of mineral reserves in the country is very difficult to obtain. Studies that attempted to provide estimates of mineral reserves in Ghana are OpenOil (2012), Federal Research Division (1995), Boyle (2008) and Bermúdez-Lugo (2009). Estimates of diamond reserves by OpenOil (2012) for the year 2010 was 100 million carats with 8,728,500 ct proven, while proven and probable reserves of diamond by the Federal Research Division (1995) was 11, 000,000 ct .Using the work of Precious Minerals Marketing Company (2016) which estimates that annual diamond production in Ghana is on the average about 500,000 carat, the use of the diamond reserve estimates by Federal Research Division (1995) will imply that diamond reserves would have been depleted by now which is not probable. We therefore use estimates of diamond reserves by OpenOil (2012).

Boyle (2008) and Bermúdez-Lugo (2009) estimate manganese reserves to be 60 million tons while OpenOil (2012) estimated 49 million tons of unproven reserves and 4.9 million tons of proven reserves of manganese in 2010. We use the overall estimates provided by OpenOil (2012) since it is the most recent.

Table 3.1: Bauxite Deposit in Ghana (million tons)

Reserve Type	2013	2012	2011
Mineable	11.95	14.08	15.04
Geological	11.95	14.08	15.04
Inferred	16.2	18.19	19.15

Source: Minerals Commission, 2015

Table 3.1 provides information on bauxite deposits in Ghana. OpenOil (2012) estimated 400 million tons of unproven reserves and 18,911,900 tons of proven reserves of bauxite in Ghana in 2010. We use the geological reserves obtained from the MC in the accounting. Since information on the reserves for the base year (2006) and other years up to 2010 was not available, we used a backward process where the extraction for the previous year was subtracted from the current reserves to obtain the reserves for the previous year.

Ideally, the compilation of gold AA should have included both information from LSM and SSM. However, in the compilation of the gold asset account only information on LSM were available for the AA. As earlier discussed, there is no geological information on reserve positions of SSM. Thus, no physical account was compiled for SSM. Information on gold reserves of the LSM are available on individual company basis. The metal content of the ore varies by company and therefore it became necessary to compute physical

account for each company and aggregate it to form the national accounts. In all, 12 producing companies were considered. These included Newmont Ghana Gold Limited – Ahafo Mine, Newmont Golden Ridge Limited – Akyem Mine, Gold Fields Ghana Limited – Tarkwa Mine, Abosso Goldfields Ghana Limited - Damang, Perseus Mining Ghana Limited/ Central African Gold – Edikan Mine, AngloGold Ashanti-Obuasi, Adamus/Endeavour Mining Corporation –Nzema Mine, Chirano Gold Mine, Golden Star Resources - Bogoso/Pestea, Golden Star Resources – Wassa, Noble Gold Bibiani Limited/Mensen, AngloGold Ashanti – Iduapriem.

Annual average ore grade for each of the companies for the accounting years were established by averaging the monthly average ore grades. Gold production figures for the companies were obtained from the MC in ounces and the reserves in tons. The annual average ore grades were therefore used to convert the reserves into ounce for each accounting year. The data from the MC did not contain information on other volume changes hence the physical account does not contain information on other volume changes.

3.2.2   Monetary Account

Monetary accounts were compiled for bauxite, manganese and gold to put monetary values on the changes occurring in these minerals over the years under study but not for diamond. The study could not develop monetary accounts for diamond because diamonds are mined on mainly small-scale bases and there is no information on their cost structure. Gold monetary account was computed for the 12 members of the Ghana Chamber of Mines (GCM) by aggregating all their costs and revenue. Development of the monetary account requires the calculation of resource rent and therefore it was computed for gold, manganese and bauxite.

The main components of the resource rent calculation include:

- Revenue
- Intermediate consumption- made up of electricity (power), diesel, local supplies, and imported consumables.
- Compensation of employees
- Consumption of fixed capital (depreciation of property, plant and equipment)
- Return on capital stock

The monetary accounts for gold, manganese and bauxite were compiled using the **Net Price Method (NPM) and the El Serafy Method (ESM) or User Cost Method (UCM)**. The **Net Price Method (NPM)** is the resource volume (Qt) multiplied by the difference between the average market value per unit of the resource (Pt) and the per unit (marginal) cost of extraction, development, and exploration, including a normal rate of return to capital (Ct). Mathematically, the resource rent (V_t):

$$Vt = (Pt - Ct)Qt$$

It is simply the current resource rent per unit of mineral resources multiply by the size of the mineral stock. The user cost or the discounted net revenue from the sale of the resource is given as:

$$X = R * [1-(1/(1+r)^{n+1})]$$

Where

R is the annual net revenue from the sale of the resource, X is the *true income* element-equivalent to the stream of rents received by selling the resource and depositing the mineral revenue in the bank, r is interest rate for the period and n is the years to depletion of the resource.

Data on revenue and production cost of gold, manganese and bauxite were obtained from the GCM from 2006 to 2014. The cost data for gold, manganese and bauxite were provided in US dollars and in Ghana Cedis (GHC). To make the data more uniform, they were all converted to US dollars using annual exchange rate from the Bank of Ghana from 2006 to 2014. Compensation of employees paid by the gold, manganese and bauxite mining companies for 2006 and 2007 were not provided by the GCM. Therefore, a regressing model was used to extrapolate the compensation of employees for the years 2006 and 2007. With respect to the calculation of consumption of fixed capital (depreciation) by the mining companies, 20% depreciation rate was used. The net book value for plants, machinery and other capital equipment for gold, manganese and bauxite were carried forward into the next year as opening balances. Discussions at the workshop suggested that return on capital investments in the mining sector ranges from 12 to 17 percent. In order to enable some sensitivity analysis, returns on capital investments of 12, 15 and 17 percent were used. Also, in the computation of the UCM, annual dollar interest from 2006 to 2014 provided by the Bank of Ghana were used. The aggregate revenue and cost data were obtained from the GCM.

4 Results and Discussions

4.1 Manganese

Overall, between 2006 and 2014 a total of 12.85 million tons of manganese has been extracted at an average annual extraction rate of 1.43 million tons. Figure 4.1 shows the extraction of manganese from 2006 to 2014. Manganese extraction reduced from 2006 to 2009 but thereafter exhibited fluctuations. Manganese extraction attained its lowest of about of 1.01 million tons 2009. The decline in production was as a result of the credit crunch that hit the global economy and decrease in global demand for manganese up to the first quarter of 2009 (GCM, 2009).

Figure 4.1: Manganese Extraction in tons from 2006 -2014
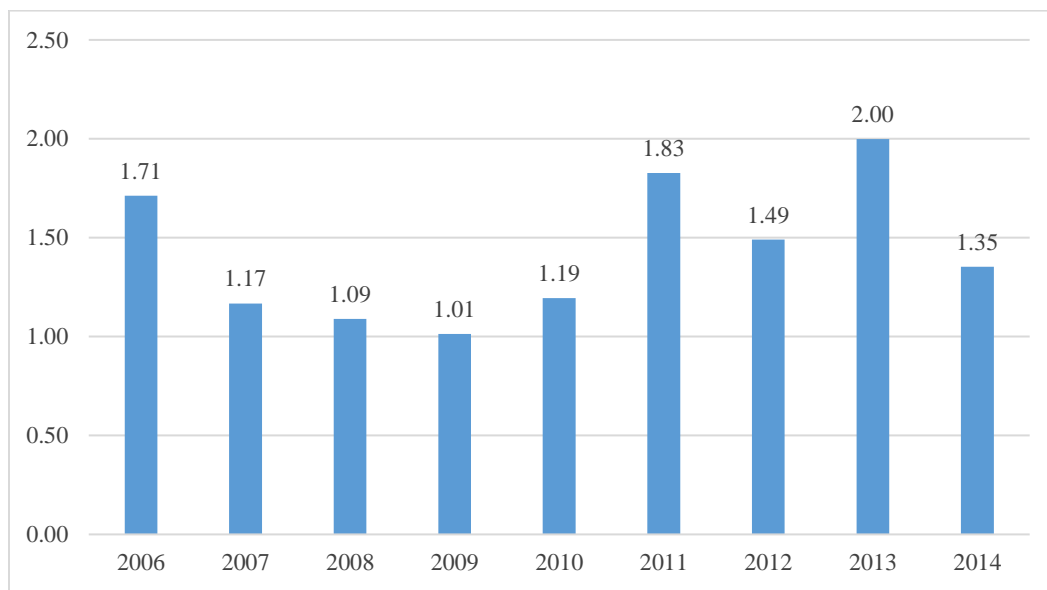
Source: Ghana Chamber of Mines (2015)

Ghana Manganese Company recorded the highest production quantity of 2.0 million tons in 2013 basically due to the company's strategic mine development in 2013.

4.1.1 Physical Account for Manganese

Using the opening stock as a measure of the reserves, it could be observed that manganese reserves reduced from about 54.0 million tons in 2006 to about 42.5 million tons in 2014. Using the extraction rate of 1.4 million tons in 2014, manganese resources will deplete in approximately 30 years, if new reserves are not found. Table 4.1 shows the physical account for manganese in tons.

Table 4.1: Physical Account for Manganese in tons

Years	Opening Stock (tons)	Extraction (tons)	Other Accum. (tons)	Other Volume Change (tons)	Closing Stock (tons)	Years to Depletion
2006	53,981,813	1,712,508	-	na	52,269,305	30.52
2007	52,269,305	1,167,339	-	na	51,101,966	43.78
2008	51,101,966	1,089,025	-	na	50,012,941	45.92
2009	50,012,941	1,012,941	-	na	49,000,000	48.37
2010	49,000,000	1,194,074	-	na	47,805,926	40.04
2011	47,805,926	1,827,692	-	na	45,978,234	25.16
2012	45,978,234	1,490,634	-	na	44,487,600	29.84
2013	44,487,600	1,997,911	-	na	42,489,689	21.27
2014	42,489,689	1,353,486	-	na	41,136,203	30.39

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

4.1.2 Monetary Account for Manganese

We calculate monetary accounts using the Net Present Method and the User Cost Method (UCM) or El Sarafy at interest rates of 12%, 15% and 17% for the period 2006 to 2014. Results of our estimates has been presented as Tables 4.2 to 4.7.

From the tables one could observe that the estimates of the monetary values of manganese resources were higher using the NPM than the UCM for all the interest rates. Also, as expected the values of the estimates were higher at lower interest rates and vice versa. A notable observation is the negative revelation obtained using the NPM for the years 2010, 2012, 2013 and 2014, and for the years 2007, 2008, 2012 and 2014 using the UCM. This can be attributed to the reduction in resource rent from the previous years.

Table 4.2: Monetary Account for Manganese using NPM at 12%Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	876,779,980	27,814,789		na	0	848,965,191
2007	848,965,191	20,656,972		na	75,980,839	904,289,057
2008	904,289,058	25,014,158		na	269,488,090	1,148,762,989
2009	1,148,762,990	32,754,413		na	468,453,131	1,584,461,708
2010	1,584,461,708	31,599,268		na	-287,754,703	1,265,107,737.00
2011	1,265,107,738	63,839,643		na	404,710,411	1,605,978,505
2012	1,605,978,505	49,670,073		na	-73,917,487	1,482,390,945
2013	1,482,390,945	52,918,264		na	-304,056,890	1,125,415,791
2014	1,125,415,791	28,201,545		na	-2,400,908,967	857,123,350

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

Table 4.3: Monetary Account for Manganese using UCM at 12% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	16,033,562	508,645		na	0	15,524,916
2007	15,524,916	60,551		na	-12,813,653	2,650,712
2008	2,650,712	53,404		na	-144,773	2,452,535
2009	2,452,535	93,323		na	2,155,205	4,514,417
2010	4,514,417	920,119		na	33,243,562	36,837,860
2011	36,837,860	8,924,471		na	196,594,580	224,507,968
2012	224,507,968	4,766,614		na	-77,482,941	142,258,413
2013	142,258,413	9,185,236		na	62,269,780	195,342,957
2014	195,342,957	3,834,370		na	-74,971,426	116,537,161

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

Table 4.4: Monetary Account for Manganese Using Net Price Approach At 15% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	875,044,689	27,759,739		na		847,284,950
2007	847,284,950	20,439,244		na	67,911,985	894,757,691
2008	894,757,691	24,532,176		na	256,402,666	1,126,628,178
2009	1,126,628,178	31,973,058		na	452,009,325	1,546,664,445
2010	1,546,664,445	30,578,226		na	-291,856,902	1,224,229,317
2011	1,224,229,317	63,022,810		na	424,223,368	1,585,429,875
2012	1,585,429,875	48,779,511		na	-80,838,011	1,455,812,353
2013	1,455,812,353	51,621,768		na	-306,347,453	1,097,843,132
2014	1,097,843,132	26,826,629		na	-255,680,642	815,335,860

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

Table 4.5: Monetary Account for Manganese Using UCM at 15% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	16,001,829	507,639		na		15,494,190
2007	15,494,190	59,913		na	-12,811,504	2,622,773
2008	2,622,773	52,375		na	-165,119	2,405,279
2009	2,405,278	91,097		na	2,092,544	4,406,725
2010	4,406,725	890,388		na	32,131,210	35,647,547
2011	35,647,547	8,810,282		na	194,798,104	221,635,370
2012	221,635,370	4,681,151		na	-77,246,434	139,707,785
2013	139,707,785	8,960,198		na	59,809,473	190,557,059
2014	190,557,057	3,647,432		na	-76,054,023	110,855,604

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

Table 4.6: Monetary Account for Manganese Using Net Price Approach at 17% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	873,887,829	27,723,039		na	0	846,164,790
2007	846,164,790	20,294,092		na	62,532,748	888,403,446
2008	888,403,446	24,210,854		na	247,679,044	1,111,871,637
2009	1,111,871,637	31,452,154		na	441,046,788	1,521,466,270
2010	1,521,466,270	29,897,531		na	-294,591,702	1,196,977,037
2011	1,196,977,037	62,478,254		na	437,232,005	1,571,730,788
2012	1,571,730,788	48,185,804		na	-85,451,693	1,438,093,292
2013	1,438,093,292	50,757,437		na	-307,874,495	1,079,461,359
2014	1,079,461,359	25,910,019		na	-266,073,806	787,477,534

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

Table 4.7: Monetary Account for Manganese Using UCM at 17% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	15,980,673	506,968		na		15,473,706
2007	15,473,706	59,487		na	-12,810,071	2,604,147
2008	2,604,147	51,689		na	-178,684	2,373,775
2009	2,373,775	89,613		na	2,050,770	4,334,931
2010	4,334,931	870,567		na	31,389,641	34,854,006
2011	34,854,006	8,734,155		na	193,600,454	219,720,304
2012	219,720,304	4,624,176		na	-77,088,763	138,007,366
2013	138,007,366	8,810,173		na	58,169,268	187,366,461
2014	187,366,461	3,522,807		na	-76,775,755	107,067,899

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

4.2 Diamond

An estimated 4.0 million carats of diamond were extraction from 2006 to 2014 at an average extraction rate of about 440 thousand carats. From the physical account table, diamond extraction and shipment decreased from 973 thousand carats in 2006 to 161 thousand in 2013. This could be attributed to the collapse of the Ghana Consolidated Diamond Limited and the global economic down turn. Diamond production increased by approximately 50% from 160,821.00 carat in 2013 to 241,325.00 carat in 2014. The extraction and shipment of diamond from 2006 to 2014 is shown in Figure 4.2.

Figure 4.2: Diamond Production ('000' carat) from 2006 to 2014
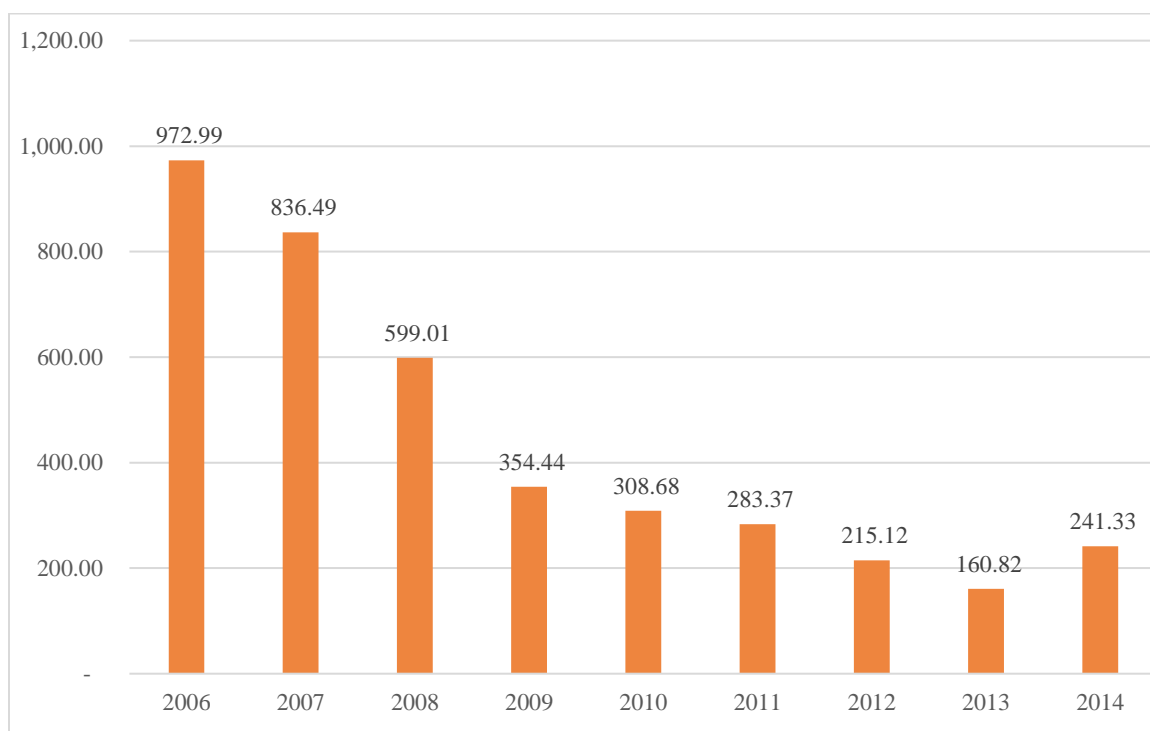
Source: Ghana Chamber of Mines, 2015

4.2.1 Physical Account for Diamond

The slow extraction of diamond resources suggests that it will take a long time for it to be depleted. Using the extraction rate of 215,118 ounces in 2014, diamond resources will be depleted in approximately 461 years, if new reserves are not found (Table 4.8). Only physical accounts for diamond was calculated due to the lack of data on the cost of diamond mining activities.

Table 4.8: Physical Account for Diamond in Carats

Years	Opening Stock (tons)	Extraction (tons)	Other Accum. (tons)	Other Volume Change (tons)	Closing Stock (tons)	Years to Depletion
2006	102,762,930	972,992			101,789,938	104.62
2007	101,789,938	836,488			100,953,450	120.69
2008	100,953,450	599,007			100,354,443	167.53
2009	100,354,443	354,443			100,000,000	282.13
2010	100,000,000	308,679			99,691,321	322.96
2011	99,691,321	283,369			99,407,952	350.81
2012	99,407,952	215,118			99,192,834	461.11
2013	99,192,834	160,821			99,032,013	615.79
2014	99,032,013	241,325			98,790,688	409.37

Source: Authors calculations with data from OpenOil (2012) and Ghana Chamber of Mines (2015)

4.3   Bauxite

A total of 5.21 million tons of bauxite was extracted from 2006 to 2014. On average 651,806.63 tons of bauxite was extracted on annual basis. The highest extraction quantity within the period was 885,770 tons which occurred in 2006. This can be attributed to the continuous improvement in decision taken by the Ghana Bauxite Company in the previous years (GCM, 2006).

Figure 4.3: Bauxite Extraction in tons from 2006 to 2013

Source: Ghana Chamber of Mines, 2015

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4.3.1 Physical Account for Bauxite

Bauxite extraction fell from 2006 to 2009 and exhibited fluctuations in 2010 and 2011. It however began to increase again from 2012 to 2013. The lowest extraction quantity of 400,069.00 tons was recorded in 2011. Figure 4.3 shows the quantity of bauxite extracted from 2006 to 2013. At an extraction rate of 826 thousand tones, bauxite reserves will be depleted in the next 47 years if more reserves are not discovered.
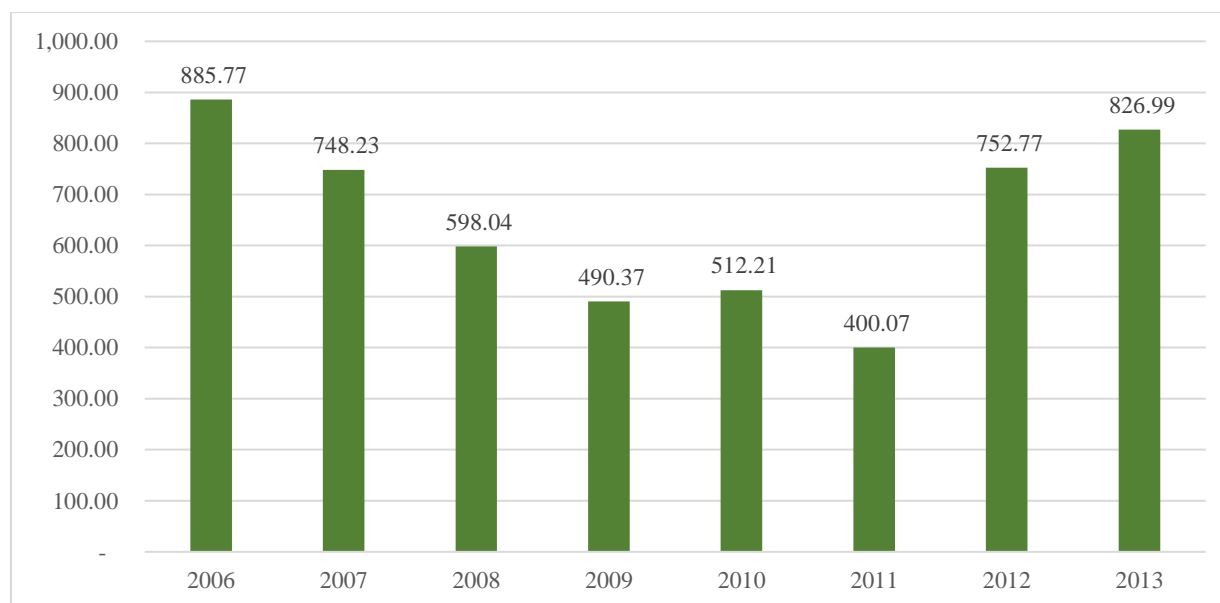
Table 4.9: Physical Account for Bauxite in tons

Years	Opening Stock (tons)	Extraction (tons)	Other Accum. (tons)	Other Volume Change (tons)	Closing Stock (tons)	Years to Depletion
2006	18,274,619	885,770		885,770.00	17,388,849	19.63
2007	17,388,849	748,232		748,232	16,640,617	22.24
2008	16,640,617	598,042		598,042	16,042,575	26.83
2009	16,042,575	490,367		490,367	15,552,208	31.72
2010	15,552,208	512,208		512,208	15,040,000	29.36
2011	15,040,000	400,069			14,639,931	36.59
2012	14,639,931	752,771	14,080,000		27,967,160	37.15
2013	27,967,160	826,994	11,950,000		39,090,166	47.27
2014	39,090,166				39,090,166	

Source: Authors calculations with data from MC (2015) and GCM (2015)

4.3.2 Monetary Account for Bauxite

Monetary accounts for bauxite were calculated using the Net Present Method and the UCM or El Sarafy at interest rates of 12%, 15% and 17% from 2006 to 2013. Results of the monetary accounts for bauxite has been presented as Table 4.10 to 4.15. The monetary accounts using the NPM yield higher values than the UCM. Negative revaluation amounts were recorded for both NPM and UCM at interest rates of 12%, 15% and 17% for the years 2007, 2008, 2009 and 2011. However, the UCM recorded negative revaluation amount in 2013 at interest rates of 12%, 15% and 17%.

Table 4.10: Monetary Accounts for Bauxite using NPM at 12% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	376,357,110	18,242,013			0	358,115,097
2007	358,115,097	14,753,879			-15,236,196	328,125,023
2008	328,125,023	9,431,239			-65,699,247	252,994,537
2009	252,994,537	3,683,415			-132,489,985	116,821,137
2010	116,821,137	7,408,067			108,110,515	217,523,585
2011	217,523,585	2,823,230			-111,388,449	103,311,906
2012	103,311,906	10,584,783			300,521,708	393,248,831
2013	393,248,831	14,124,143			288,492,105	667,616,794
2014	667,616,794				-667,616,794	

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.11: Monetary Account for Bauxite using UCM at 12% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	27,426,025	1,329,338.26		885,770		26,096,687
2007	26,096,687	714,915.97			-9,482,100	15,899,671
2008	15,899,671	246,011.21			-9,054,369	6,599,291
2009	6,599,291	75,811.61			-4,119,081	2,404,399
2010	2,404,399	541,154.72			14,026,720	15,889,965
2011	15,889,965	166,954.95			-9,613,541	6,109,469
2012	6,109,469	582,970.72			16,132,194	21,658,692
2013	21,658,692	317,256.98			(6,345,404	14,996,032
2014	14,996,032					

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.12: Monetary Account for Bauxite Using Net Price Approach at 15% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	375,714,031	18,210,843			0	357,503,188
2007	357,503,188	14,728,943			-15,203,798	327,570,448
2008	327,570,448	9,380,420			-66,558,713	251,631,314
2009	251,631,314	3,568,958			-134,871,273	113,191,083
2010	113,191,083	7,315,641			108,934,234	214,809,677
2011	214,809,677	2,475,678			-121,740,241	90,593,758
2012	905,937,578	10,202,470			298,653,735	379,045,023
2013	379,045,023	13,777,508			285,964,645	651,232,160
2014	651,232,160					

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.13: Monetary Account for Bauxite Using UCM at 15% interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	27,379,163	1,327,067		-		26,052,096
2007	26,052,097	713,708			-9,465,589	15,872,799
2008	15,872,799	244,686			-9,064,381	6,563,731
2009	6,563,732	73,456			-4,160,590	2,329,686
2010	2,329,686	534,403			13,896,433	15,691,715
2011	15,691,715	146,402			-10,187,947	5,357,366
2012	5,357,366	561,914			16,080,947	20,876,399
2013	20,876,399	309,471			-5,938,929	14,627,999
2014	14,627,999					

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.14: Monetary Account for Bauxite Using Net Price Approach at 17% interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	375,285,312	18,190,063			0	357,095,249
2007	357,095,249	14,712,319			-15,182,199	327,200,732
2008	327,200,732	9,346,541			-67,131,692	250,722,499
2009	250,722,499	3,492,653			-136,458,798	110,771,048
2010	110,771,048	7,254,023			109,483,380	213,000,404
2011	213,000,404	2,243,976			(128,641,436	82,114,991
2012	82,114,991	9,947,594			297,408,420	369,575,818
2013	369,575,818	13,546,419			284,279,672	640,309,071
2014	640,309,071					

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.15: Monetary Account for Bauxite Using UCM at 17% interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006	27,347,921	1,325,553				26,022,368
2007	26,022,368	712,902			-9,454,582	15,854,884
2008	15,854,884	243,809			-9,071,056	6,540,026
2009	6,540,026	71,885			(4,188,264	2,279,877
2010	2,279,877	529,902			13,809,574	15,559,549
2011	15,559,549	132,700			-10,570,884	4,855,965
2012	4,855,965	547,877			16,046,782	]20,354,870
2013	20,354,870	304,280			-5,667,946	14,382,645
2014	14,382,645					

Source: Authors calculations with data from MC (2015) and GCM (2015)

4.4   Gold

Aggregated gold physical accounts in tons and ounces for all gold mining companies of the GCM are presented in Table 4.16 and Table 4.17. Approximately, about 7.54 billion tons and 501 million ounces of proven and probable gold reserves were recorded from 2006 to 2014. Averagely, 837.80 million tons and 55.67 million ounces of gold reserves were recorded annually. Figure 4.4 shows gold reserves in tons and ounce from 2006 to 2014.

Figure 4.4: Gold Reserves from 2006 to 2014 in million tons and ounces
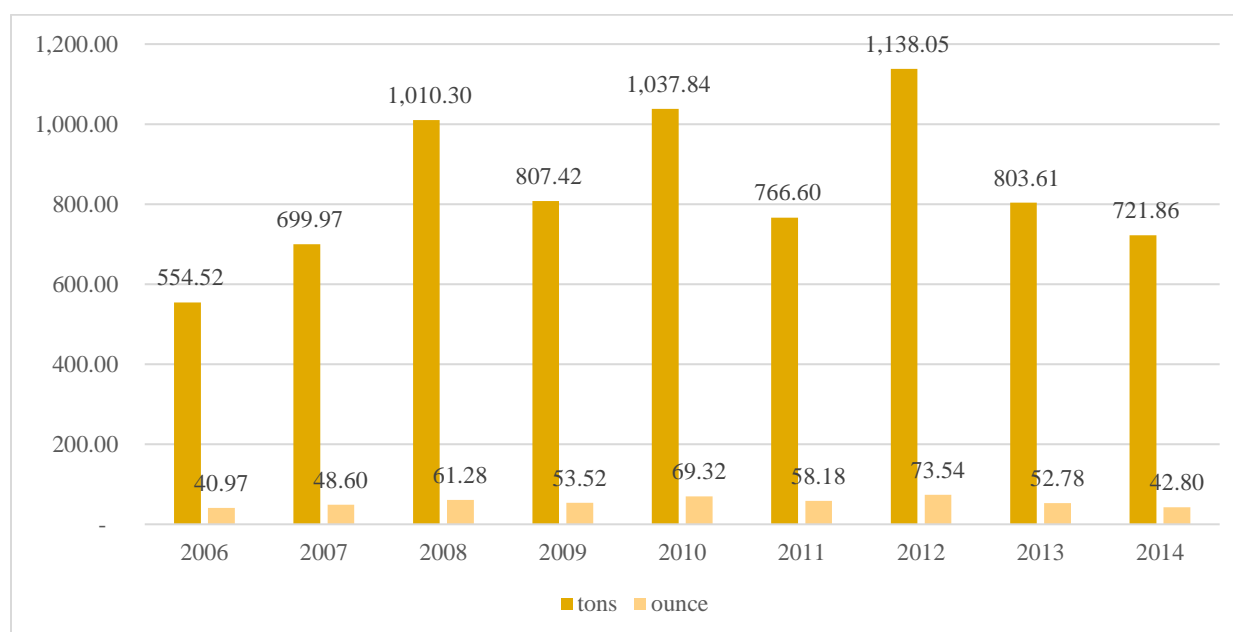
Source: Minerals Commission, 2015

4.4.1   Physical Account for Gold

With regards to extraction, approximately 23.58 million ounces and 468.71 million tons of gold were extracted by GCM members from 2006 to 2014. On average, about 2.62 million ounces or 52.08 million tons of gold were extracted annually by the GCM members. Gold extraction increased consistently from 2006 to 2011. The highest extraction of about 2.93 million ounces or 60.22 million tons of gold was observed in 2011. This was due to the increase in global average unit price of gold (GCM, 2015). However, gold extraction fell in 2012 as a result of a fall in production by major mining companies such as AngloGold Ashanti Obuasi, Gold Fields Tarkwa, Gold Fields Damang, Golden Star Bogoso Prestea Limited and Chirano Gold Mines (GCM, 2015). Figure 4.5 shows the quantity of gold extracted from 2006 to 2014 in million tons and ounce.

Figure 4.5: Gold Extraction from 2006 to 2014 in million tons and ounces
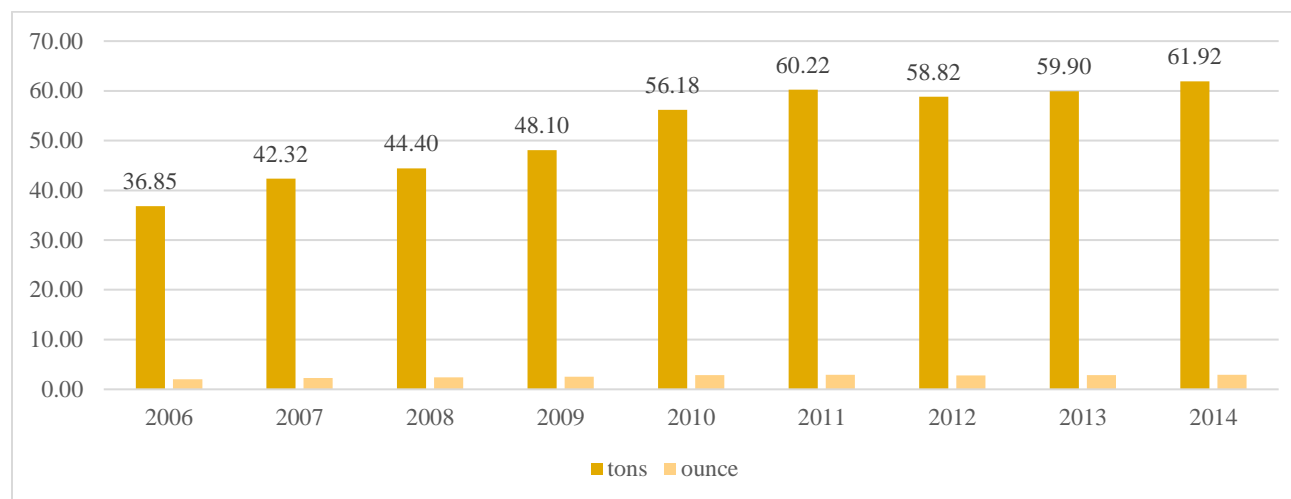
Source: Ghana Chamber of Mines, 2015

Table 4.16: Physical Account for Aggregated Gold in ounces

Years	Opening Stock (ounce)	Extraction (ounce)	Other Accum. (tons)	Other Accum. (ounce)	Other Volume Change (ounce)	Closing Stock (ounce)	Years to Depletion
2006		2,044,840	54,517,528	40,966,690	na	39,123,977	19.13
2007	39,123,977	2,247,490	699,968,094	48,602,328	na	85,478,815	38.03
2008	85,478,815	2,383,459	1,010,302,231	61,280,470	na	144,375,826	60.57
2009	144,375,826	2,563,675	807,421,617	53,524,195	na	195,336,346	76.19
2010	195,336,346	2,846,379.00	1,037,840,149	69,320,968	na	261,810,935	91.98
2011	261,810,935	2,934,665.00	766,600,000	58,175,166	na	317,051,437	108.04
2012	317,051,437	2,808,989.00	1,138,048,000	73,537,842	na	387,780,290	138.05
2013	387,780,290	2,853,810	803,607,000	52,784,471	na	437,710,950	153.38
2014	437,710,950	2,892,751	721,863,000	42,803,091	na	477,621,290	165.11

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.17: Physical Account for Aggregated Gold in tons

Years	Opening Stock (tons)	Extraction (tons)	Other Accum. (tons)	Other Volume Change (tons)	Closing Stock (tons)	Years to Depletion
2006		36,849,190	554,517,528	na	519,635,911	14.1
2007	519,635,911	42,324,290	699,968,094	na	1,180,233,648	27.89
2008	1,180,233,648	44,396,924	1,010,302,231	na	2,148,638,736	48.4
2009	2,148,638,736	48,101,355	807,421,618	na	2,912,484,397	60.55
2010	2,912,484,397	56,176,602	1,037,840,149	na	3,898,640,525	69.4
2011	3,898,640,525	60,222,466	766,600,000	na	4,608,609,653	76.53
2012	4,608,609,652	58,824,700	1,138,048,000	na	5,693,505,965	96.79
2013	5,693,505,965	59,896,575	1,569,327,000	na	7,208,314,337	120.35
2014	7,208,314,337	61,921,798	721,863,000	na	7,874,321,772	127.17

Source: Authors calculations with data from MC (2015) and GCM (2015)

4.4.2 Monetary Account for Gold

The aggregated gold monetary accounts were calculated using the Net Present Method and the User Cost Method at interest rates of 12%, 15% and 17% from 2006 to 2014. The monetary accounts are presented in Tables 4.18 to 4.23. Higher monetary values were recorded using the NPM compared to the UCM. Also, the NPM at 12%, 15% and 17% interest rates recorded negative revaluation amounts for 2007, 2008, 2013 and 2014 while the UCM at 12%, 15% and 17% interest rates recorded negative revaluation amounts for 2007, 2008, 2009, 2011, 2012 and 2012. The negative revaluation amounts can be attributed to the decrease in the resource rent from the previous year. The inconsistencies in the revaluation amounts using NPM and UCM are on the account of the changes in the interest rates as reported by the Bank of Ghana over the period under consideration.

Table 4.18: Monetary Account for Gold Using Net Price Method at 12% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006		959,862,429	19,230,055,558	Na	94,879,850	18,365,072,979
2007	18,365,072,980	1,000,606,575	21,638,275,957	na	-946,660,045	38,056,082,315
2008	38,056,082,315	557,337,658	14,329,557,921	na	-18,068,088,985	33,760,213,594
2009	33,760,213,594	1,017,940,850.47	21,252,484,901	na	23,566,105,665	77,560,863,310
2010	77,560,863,310	1,586,165,875	38,629,625,291	na	31,291,768,833	145,896,091,559
2011	145,896,091,559	1,836,174,649	36,399,304,759	na	17,914,974,498	198,374,196,168
2012	198,374,196,168	2,085,523,462	54,597,897,982	na	37,019,466,770	287,906,037,459
2013	287,906,037,459	1,874,284,190	34,667,023,863	na	-33,225,289,241	287,473,487,891
2014	287,473,487,891.00	1,457,709,238.34	21,569,247,293.71	na	-66,903,070,157.70	240,681,955,788.90

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.19: Monetary Account for Gold Using El Sarafy Method at 12% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006		74,515,111	1,492,849,067.75	na	7,365,621	1,425,699,577
2007	1,425,699,577	6,197,516	134,022,267.96	na	-1,317,814,124	235,710,205
2008	235,710,205	174,483	4,486,078.02	na	(229,452,671	10,569,129
2009	10,569,129	106,733	2,228,362.04	na	-4,558,360	8,132,399
2010	8,132,399	525,315	12,793,566.64	na	27,918,000	48,318,651
2011	48,318,651	503,248	9,976,112.96	na	-3,422,252	54,369,263
2012	54,369,263	53,770	1,407,658.46	na	-48,300,277	7,422,875
2013	7,422,874.95	10,004	185,036.04	na	-6,063,511	1,534,396
2014	1,534,396	37,871	560,371	na	4,196,046	6,252,942

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.20: Monetary Account for Gold Using Net Price Method at 15% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006		945,758,782	18,947,500,563	na	19,040,986,305	18,095,227,523
2007	18,095,227,523	973,344,376	21,048,726,576	na	19,897,335,609	37,019,218,756
2008	37,019,218,756	515,798,768	13,261,562,744	na	(5,259,386,272	31,244,033,716
2009	31,244,033,716	969,836,618	20,248,168,72	na	43,621,418,112	73,895,615,210
2010	73,895,615,210	1,527,173,336	37,192,915,751	na	68,101,495,408	140,469,937,281
2011	140,469,937,281	1,764,622,398	34,980,892,739	na	51,938,614,279	190,643,929,163
2012	190,643,929,162.66	1,994,643,846.00	52,218,717,856.00	na	86,710,841,995	275,360,127,311.29
2013	275,360,127,311	1,792,809,358	33,160,053,927	na	1,409,743,788	274,977,061,741
2014	274,977,061,740.63	1,378,662,513.02	20,399,618,727.71	na	-45,967,825,667.24	227,630,573,560.37

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.21: Monetary Account for Gold Using El Sarafy Method at 15% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006		73,420,231	1,470,914,032	na	7,257,395	1,404,751,196
2007	1,404,751,196	6,028,661	130,370,741	na	-1,299,805,154	229,288,122
2008	229,288,122	161,478	4,151,726	na	-223,496,968	9,781,402
2009	9,781,402	101,689	2,123,058	na	-4,054,680	7,748,091
2010	7,748,091	505,777	12,317,749	na	26,961,525	46,521,588
2011	46,521,588	483,638	9,587,363	na	-3,374,717	52,250,596
2012	52,250,596	51,426	1,346,318	na	-46,446,075	7,099,413
2013	7,099,413	9,569	176,992	na	-5,799,140	1,467,696.00
2014	1,467,696	35,818	529,984	na	3,952,003	5,913,866

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.22: Monetary Account for Gold Using Net Price Method At 17% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006		9,363,563,450	18,759,130,566		92,556,337	17,915,330,553
2007	17,915,330,553	955,169,577	20,655,693,652.95		-1,287,878,246	6,327,976,383
2008	36,327,976,383	488,106,174	12,549,565,959.03		-18,822,855,704	,566,580,464
2009	29,566,580,464	937,767,130	19,578,624,602.37		23,244,678,541	71,452,116,477
2010	71,452,116,477	1,487,844,978	36,235,109,391		30,653,120,205	136,852,501,096
2011	136,852,501,096	1,716,920,897	34,035,284,724		16,319,552,904	185,490,417,826
2012	185,490,417,825	1,934,057,436.00	50,632,597,773.00		32,807,229,050	266,996,187,212
2013	266,996,187,213	1,738,492,804	32,155,407,303		-30,766,990,738	266,646,110,974
2014	266,646,110,974	1,325,964,696	19,619,866,350		(66,010,360,55)	218,929,652,075

Source: Authors calculations with data from MC (2015) and GCM (2015)

Table 4.23: Monetary Account for Gold Using El Sarafy Method at 17% Interest Rate

Years	Opening Stock (US$)	Extraction (US$)	Other Accum. (US$)	Other Volume Change (US$)	Revaluation (US$)	Closing Stock (US$)
2006		72,690,310	1,456,290,674	na	7,185,244	1,390,785,608.19
2007	1,390,785,608	5,916,090	127,936,390	na	-1,287,799,175	225,006,733.21
2008	225,006,733	152,809	3,928,825	na	-219,526,499	9,256,251.13
2009	9,256,251	98,327	2,052,855	na	-3,718,894	7,491,886
2010	7,491,886	492,752	12,000,538	na	26,323,875	45,323,546
2011	45,323,546	470,564	9,328,196	na	-3,343,027	50,838,151
2012	50,838,151.25	49,864.42	1,305,423.97	na	-45,209,939.53	6,883,771.27
2013	6,883,771	9,279.25	171,630	na	-5,622,893	1,423,229.74
2014	1,423,230	34,448.70	509,726	na	3,789,308	5,687,815

Source: Authors calculations with data from MC (2015) and GCM (2015)

5   Challenges of the Compilation

There are a number of challenges that need to be recognized. The first challenge involves the availability of quality and relevant data. Key among this is the data on reserves of mineral resources and the cost of production. As alluded to in the relevant sections, there is no reliable data on the total reserves of manganese, bauxite, diamond and gold. There is some data on the location of reserves, however the certainty of the volume and metal content of many of the reserves remains unknown. Different figures are being provided by different Agencies as discussed in the sections making it difficult for one to know the exact volume of reserves.

The second challenge is associated with SSM. There is virtually no information on the reserves and cost of production of SSM. In addition, many of them operate illegally and therefore much is not known about them. Many of the registered SSM are given concessions even though they do not know the mineral reserves available. This has made it very difficult to include them in the accounting. There will therefore be the need to undertake studies that bring out the cost of production of small-scale operators as well as their reserves.

Another major problem was the reliability of the cost data provided. A critical look at the cost data provided suggests that some of the costs may have been omitted. This may mean that the cost data has been underestimated. Also, in the calculation of the gold accounts, there were no data on gold reserves for the year 2005 which is required to feed into the calculation of the accounts for 2006 and consequently all the other years since the calculation of current years requires information on the previous years. We will recommend that the MC changes its format for data collection from the mines to capture all the cost of the mines

6   Recommendations for Policy

In order to fully operationalize mineral resource accounting in Ghana we recommend the following actions based on our experience in compiling the current accounts:

1. Modified information being collected from the large scale-mining companies to include all data relevant to minerals accounting and should be processed regularly.
2. Undertake studies that bring out the cost of production of small-scale operators as well as their reserves.
3. Undertake a more detailed study on the concept of other volume changes so as to operationalize the inclusion of transactions that are not due to economic decisions.

7   Reference

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