Journal of African Earth Sciences 138 (2018) 348–366

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Hydro-geochemical characterizations of a platinum group element groundwater system in Africa

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ARTICLE INFO

Article history:
Received 20 March 2017
Received in revised form
20 November 2017
Accepted 22 November 2017
Available online 24 November 2017

Keywords:
Acid mine drainage
Pyrrhotite oxidation
Acid buffering
Serpentinite
Bushveld
Groundwater quality
Hydro-geochemical processes

ABSTRACT

Water is a scarce resource in the drylands of Africa and the Middle East and the identification of risks to aquifers is an important endeavor. There is a common and erroneous belief that only gold and coal deposits in Southern Africa are associated with acid-generating minerals. The study highlights the application the tools of geochemical analysis can reveal the classes of chemical reactions leading to the evolution of a shallow aquifer in an arid zone with active mining of sulfidic ore taking place.

The prevailing hydro-geochemical processes were assessed at an open cast platinum mine. Major conclusions relate to the Acid Mine Drainage buffering within fractured aquifer system associated with the platinum deposit. The oxidation of pyrrhotite from in situ sources is the major contributing factor towards AMD formation. Neutralization of acid in the groundwater system has solved the pH problem but introduced a salinity problem.

1. Introduction

Water is a scarce resource in the drylands of Africa and the Middle East and the identification of risks to aquifers is an important endeavor. The impact of acid mine drainage (AMD) on groundwater resource is one of the worse environmental concern associated with mining (Bell et al., 2001; Vermeulen and Usher, 2009).

The mining industry forms the backbone of the South African Economy. According to the Mineral Commodity Summaries (2015), South Africa is the world's largest producer of chrome, manganese, platinum, vanadium and vermiculite; and the second largest producer of ilmenite, palladium, rutile and zirconium. The country is also one of the largest coal exporters.

There is a common and erroneous belief that only gold and coal deposits in Southern Africa are associated with acid-generating minerals. This results in few investigations of the AMD potential of mining of Magmatic Sulfide Deposits in Bushveld Complex. The Platreef (Northern limb ore deposit in the BC) is known for its feldspathic pyroxenite-norite hosting one of the world class magnetic-type nickel, copper and platinum ground element (Kinnaird and McDonald, 2005). Since mid to late 1920's, the Plaatreef has become a site of platinum prospecting and mining (Buchanan, 1988).

In the process of AMD, a number of hydro-geochemical processes occur. Some of these processes are: acid neutralization/buffering, chemical precipitation, attenuation or dissolution of metals (Blowes et al., 1994). A sound hydro-geochemical conceptual model based on the site geology, hydrogeology, and mineralogy, is necessary for investigating the groundwater quality characteristics. One also needs to assess (test) the validity of each hypothetically conceived hydro-chemical reaction based on measured data.

The study aims to investigate the hydro-geochemical processes within the catchment and how they directly impact overall groundwater quality. It highlights the application of (bivariate) scatter plots, and other diagnostic plots as complimentary tools to analyze the groundwater chemistry data collected in a typical Platinum Group Element groundwater system. It specifically uses groundwater monitoring data from an open cast platinum mine to describe different hydro-geochemical process which prevail in the monitored groundwater system.

2. Description of the study area

The study area is located north-west of Mokopane town

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https://doi.org/10.1016/j.jafrearsci.2017.11.032
1464-343X/

(approximately 30 km) within Mogalakwena Municipal Area, which forms part of the Waterberg District Municipality of the Limpopo Province, in South Africa (Fig. 1). Multiple open pit mines are operated by various mining companies. The area falls in catchment A61G which is located in the Limpopo Water Management Area, and is mainly drained by the Mogalkwena River toward the North. This area is used for a more general hypothesis for Platinum Group Element groundwater system in Africa.

The area normally receives up to 860 mm of rain per year. Most rainfall occurs during summer in the form of afternoon thunderstorms (Bye and Bell, 2001; Holland, 2011).

2.1. Soils and unsaturated zone

Based on existing borehole logs, and field observations, the top soil of the area consists mostly of clay and sand of multiple colors (whitish, blackish, brown). This soil has developed as residual soil from either the igneous or sedimentary rocks. This soil may extend to 3.0 m below ground level (mbgl), but is also absent at some places. The soils are classified as follows (Soil Classification Working Group, 1991; Fey, 2010).

- Sandy, loamy soils are found on the flatter areas (Hutton and Short-lands forms);
- At the Hilly area, shallower rocky soils (Mispha forms) are generally dominant;
- And the clay (sandy clay) soils (Arcadia form) are associated with depressions.

2.2. Hydro-stratigraphic units, types, and thicknesses

The subsurface geology (up to 180.0 mbgl) is characterized by a well-developed igneous layering of Gabbro-Norite (Rustenburg layered Suit, Bushveld Complex), Granite (Utrecht, Mashashane Suit), Pyroxinite, and Gneiss (and Goudplaats-Hout River Suit). These rocks form the hangingwall and the footwall of a platiniferous horizon, known as the Platreef. It has an economic platinum group element mineralization within a sulfide-bearing pyroxenite body. The strike length of the Platreef approximates between 35 km and 40 km (Viljoen and Schürmann, 1998; Manyeruke et al., 2005). The Platreef varies in thickness, with a maximum thickness of 400 m occurring in the south, thinning to less than 50.00 m in the north (Manyeruke et al., 2005). The thickness of the Platreef at Sandsloot ranges from 70.00 to 200.00 m (Bye and Bell, 2001). Rocks in these zones include cordierite spinel hornfels, clinopyroxenites, calcsilicates and graphite-bearing serpentinites, serpentinized peridotites and pyroxenites. Between Tweefontein and Sandsloot farms, a dolomite formation (of the Transvaal Super Group) known locally as the "dolomite tongue" thins the Platreef. At the farm Townlands, the Platreef consists of three packages of medium grained gabbronorite and, feldspathic pyroxenite, separated by hornfels interlayers, with a total thickness of approximately 150.00 m (Manyeruke et al., 2005). These igneous formations are disturbed by dolerite dykes of variable sizes, as well as by faults.

Depths to water-strike were analyzed from the drilling log of 45 existing boreholes. The depths to first water-strike are normally distributed. 85% of boreholes encountered water before a depth of

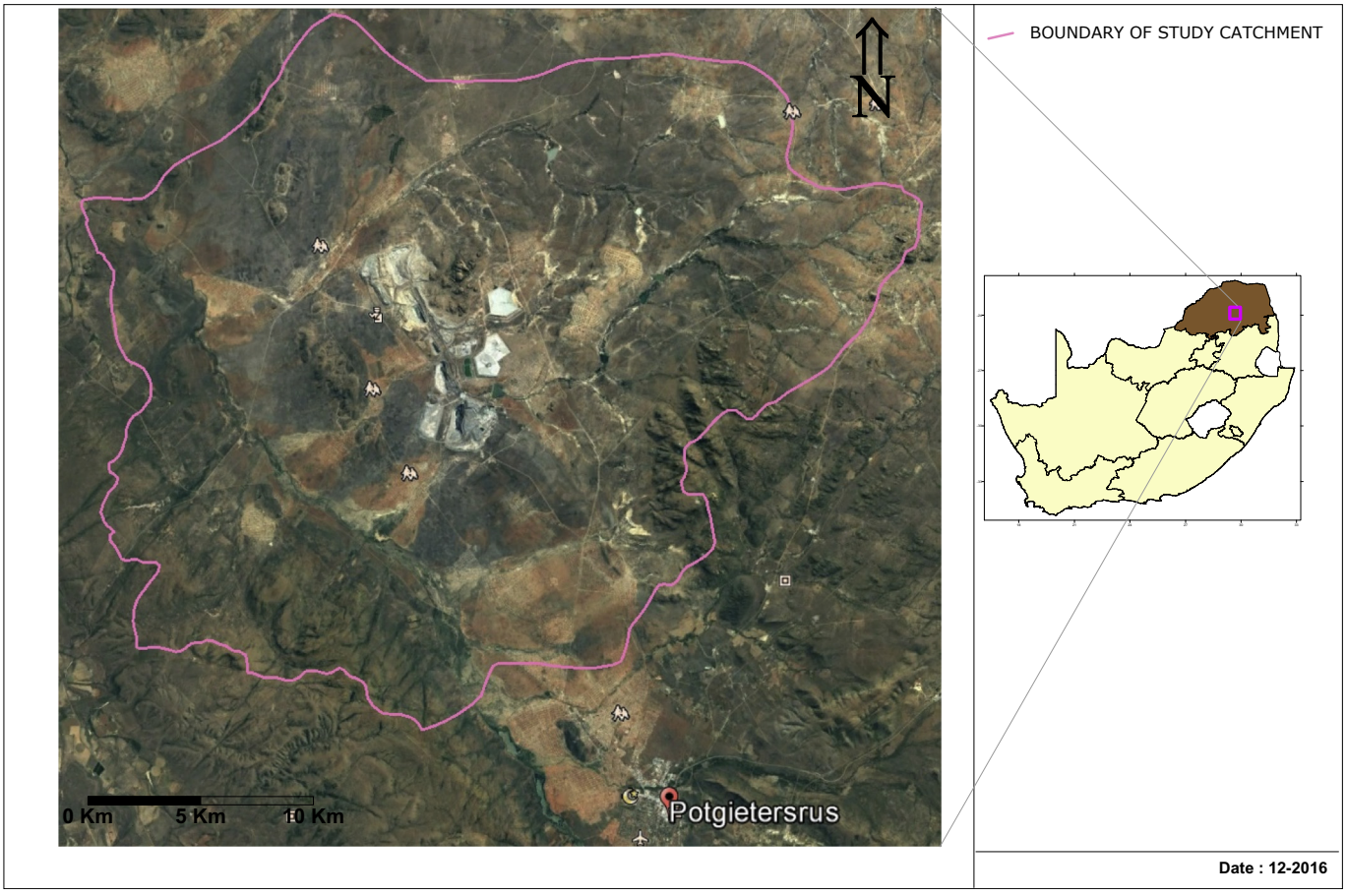

Fig. 1. Location of the study area.