Chemical Geology 228 (2006) 175–196

CHEMICAL GEOLOGY
INCLUDING
ISOTOPE GEOSCIENCE

www.elsevier.com/locate/chemgeo

The nexus between groundwater modeling, pit lake chemogenesis and ecological risk from arsenic in the Getchell Main Pit, Nevada, U.S.A.

Andy Davis [a,*], T. Bellehumeur [a], P. Hunter [a], B. Hanna [a], G.G. Fennemore [b], C. Moomaw [a], S. Schoen [b]

[a] Geomega, 2995 Baseline Road, Suite 202, Boulder, CO 80303, United States
[b] Barrick Gold Corporation, Crescent Valley, NV 89821, United States

Accepted 6 November 2005

Abstract

The proliferation of mine pits that intersect the groundwater table has engendered interest in the environmental consequences of the lakes that form after cessation of dewatering. The Getchell Main Pit (GMP) in Nevada hosts arsenic sulfide (As_xS_y) mineralization (e.g., orpiment and realgar) and ambient groundwater As up to 1.8 mg L^{-1}, making groundwater inflow a potentially significant As source to the future pit lake. Predictive simulations using MODFLOW-SURFACT show that the GMP lake water level will recover to within 99% of the pseudo-equilibrium stage within 100 years after the end of dewatering, resulting in a 75-m deep, terminal pit lake. The juvenile GMP lake (after 5 years) will be a calcium sulfate, pH 7.8 water body containing 920 mg L^{-1} TDS and 0.6 mg L^{-1} As evolving towards a pH 7.9, 1580 mg L^{-1} TDS and 0.9 mg L^{-1} As water body after 100 years. The predicted pit lake chemistry is consistent with earlier pit lake water quality after 16 years when the South and Center Pits, precursors to the Main Pit, were allowed to fill during a mining hiatus (1968–1984). The GMP mature pit lake chemistry was used to assess ecological risk to potential local receptors, i.e., mallard duck, cliff swallow, golden eagle, little brown bat, spotted sandpiper, deer mouse, mule deer and cattle. Arsenic does not strongly bioaccumulate through the food chain at Getchell; hence, pit lake As will not pose an unacceptable risk.

Keywords: Arsenic; PITQUAL; Ecological risk; Getchell Mine; Pit lake

1. Introduction

Cessation of dewatering activities at open pit mines results in the creation of a "pit lake" if the pre-mining groundwater table elevation is higher than the bottom of the pit after it is decommissioned. As part of the environmental assessment process, it is necessary to determine the potential environmental impacts of the future pit lake chemistry on (1) groundwater quality adjacent to the pit and (2) probable ecological receptors.

Existing pit lakes pre-date the onset of pit lake chemistry predictions, while those for which predictions have been made are yet to fill, hence, model verification has proved difficult. There have been several papers describing the chemistry of existing pit lakes (e.g., Davis and Ashenburg, 1989; Eary, 1999; Shevenell et al., 1999; Parshley and Bowell, 2003). However, with

* Corresponding author. Tel.: +1 303 938 8115; fax: +1 938 8123.
E-mail address: andy@geomega.com (A. Davis).

0009-2541/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.chemgeo.2005.11.023

the exception of a bench-scale test (Davis, 2003) and an analysis of the North Pit lake at Getchell (Tempel et al., 2000), there appears to be a paucity of literature pertaining to "prediction" of pit lake chemistry and its implications on post-mining uses, especially considering their number worldwide, and in particular in the western United States. For example, in Nevada alone, there are projected to be at least 35 such features that either currently contain water or will upon termination of mining at the facilities (Shevenell et al., 1999).

This paper describes a pit lake water quality study undertaken at the Getchell Main Pit (GMP), Humboldt County, ~90 km north of Golconda, NV (Fig. 1). Of particular interest in this setting is the elevated naturally occurring background arsenic (As) found in the local soils (270 mg kg^{-1}) and groundwater (1.8 mg L^{-1}) in the area.

Computing the future pit lake water quality (Fig. 2) requires initial water quantity modeling, in this case using MODFLOW-SURFACT (HydroGeoLogic, 1996), to determine the rate of infilling of the pit lake and the flow proportions through each lithologic unit (Geomega, 2003a). These data were used as inputs to PITQUAL (Davis et al., 2001), which accounts for the solute leachability from each wall rock lithology, and in combination with the flow velocity, computes temporal mass loading into the pit. The resulting bulk chemistry was input to PHREEQC (Parkhurst, 1995) to determine the dissolved pit lake chemistry, allowing chemogenetic trends to be developed (Geomega, 2003b). Finally, the predicted mature pit lake chemistry was used to assess the potential for ecological risk (Geomega, 2003c) based on a deterministic dose model (EPA, 1993a,b).

For the Main Pit lake predictions, calibration of the groundwater flow model was based on a 35-year record of environmental data. The geochemical model calibration was compared to empirical laboratory test results (leaching, geotechnical, geochemical, etc.). Uncertainty in groundwater and geochemical model results were quantified with statistical tests and with sensitivity analyses, where critical parameters (e.g., recharge) were varied by ±10%. Additionally, both models were

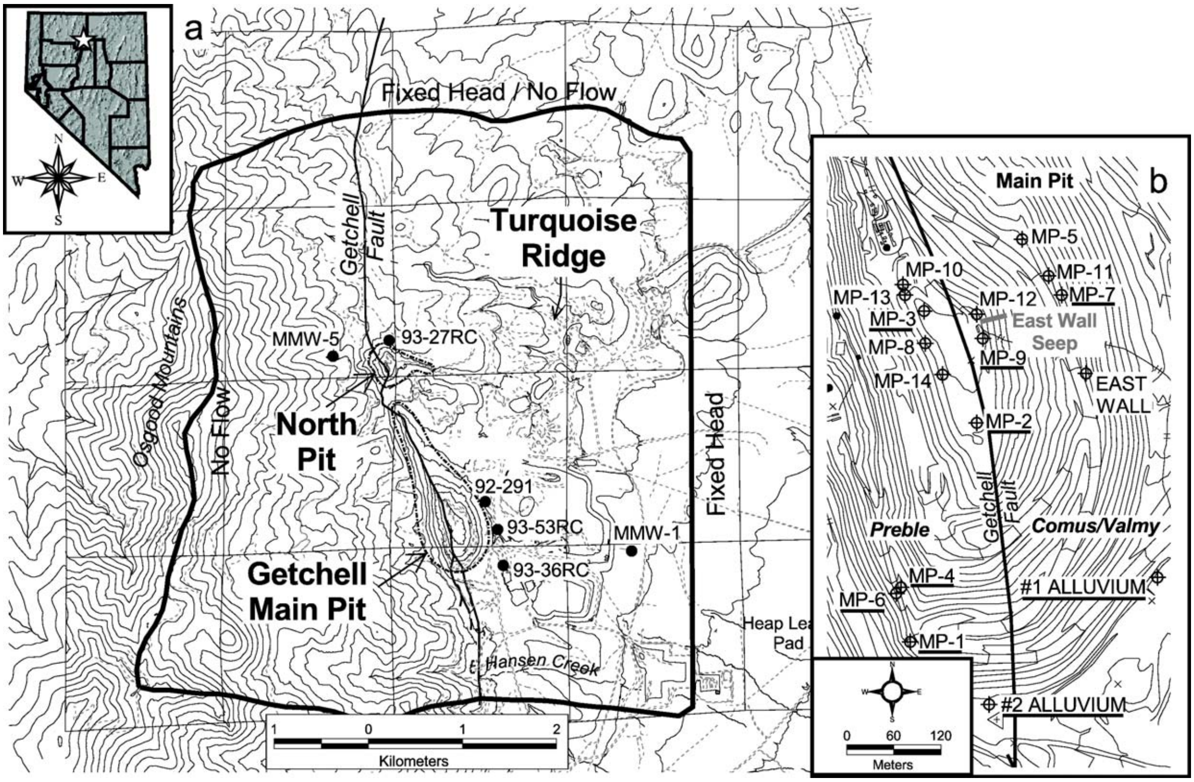

Fig. 1. (a) Getchell model domain with 30 m topographic contours showing the location of the GMP, North Pit and Turquoise Ridge underground mine, the model boundary conditions and a subset of the monitoring wells used in transient calibration of the model (Fig. 6); and (b) GMP lithologies, showing locations for the seep samples (data in Table 2), and the GMP UPS samples with the subset used in humidity cells (Table 1) underlined. Topographic contours are 6 m.