

Selenium and tellurium resources in Kisgruva Proterozoic volcanogenic massive sulphide deposit (Norway)

Liam A. Bullock^{a,b,*}, Magali Perez^c, Joseph G. Armstrong^a, John Parnell^a, John Still^a, Joerg Feldmann^c

^a School of Geosciences, University of Aberdeen, Aberdeen AB24 3UE, UK

^b Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, Southampton SO17 1BJ, UK

^c Trace Element Speciation Laboratory (TESLA), Department of Chemistry, University of Aberdeen, Aberdeen AB24 3UE, UK



ARTICLE INFO

Keywords:

Selenium
Tellurium
Sulphide ore
Pyrite
VMS
Norway

ABSTRACT

The former mining site at Kisgruva near Kongsberg, Norway, is primarily composed of worked sulphide ore deposits, of hydrothermal origin, which occur within Precambrian metamorphic basement. Though the original targets at the Kisgruva mine site were extraction of copper (Cu), sulphur (S) and iron (Fe), the sulphide ore also contains exceptionally high concentrations of selenium (Se) and tellurium (Te), hosted within selenides (clausthalite and minor naumannite) and tellurides (hessite and minor altaite and tellurobismuthite). Both Se and Te are also present within the sulphide ore in pyrite and chalcopyrite, which contain exceptionally high concentrations of up to 688 ppm Se and 81 ppm Te. Additionally, oxidative weathering of the exposed bedrock has resulted in the accumulation of hyper-enriched, unconsolidated weathered crust deposits at surface (Se up to 1590 ppm; Te up to 63 ppm), containing selenite (SeO_3^{2-}) and tellurite (TeO_3^{2-}) ions. Concentrations of Se and Te are subsequently higher in the weathering products than in the sulphide ore, due to fixation on to organic matter (~0.4% in weathered ore crusts), jarosite (formed from oxidation of sulphides from the primary ore), ferric oxide and hydroxide phases (goethite and haematite). Increasing demand for Se and Te to use in green technologies has led to the reassessment of these orebodies and their associated weathered ore crust deposits. Though these elements are currently considered mining contaminants, this and similar sites may be of future economic importance, particularly as demand for Se and Te continues to rise.

1. Introduction

A greater knowledge of how critical element such as selenium (Se) and tellurium (Te) concentrate and are spatially distributed in solid ore rock and the associated weathered profile is of increasing economic importance. This is particularly relevant as the worldwide demand for viable sources of Se and Te continue to grow. The former Kisgruva sulphide mine in the Kongsberg region of Buskerud (Norway) is known to host high Se and Te concentrations, though well-constrained data from the region are limited (NGU, 1981, 2017; Bjerkgård, 2015; Kotková et al., 2018). This is in part due to the historically low economic importance of Se and Te. Concentrated Se from ore extraction activities is presently considered toxic, particularly relating to its liberation and release from mining sites (Lemly, 2004; Sandy et al., 2010; Khamkhash et al., 2017). Tellurium is also toxic in high concentrations (Pohl, 2011; Schirmer et al., 2014), particularly in the form of tellurite (TeO_3^{2-} ; Templeton et al., 2000; El-Shahawi et al., 2013). However, in

recent years, Se and Te have become critical 'E-tech' elements, used in alloys, photovoltaic products and nanotechnologies (Ba et al., 2010; Belzile and Chen, 2015; Jin et al., 2016; Wei et al., 2016), and minerals such as pyrite should be considered a potential source of economic interest for these elements (Keith et al., 2017). The growing necessity for sources of E-tech elements has led to an increasing focus on new potential concentrated Se and Te deposits and a review of former ore mining sites, such as the Kisgruva site.

The Kisgruva site is part of the greater Kongsberg mining region (Fig. 1). Vein deposits in banded diorite, granitic gneiss and amphibolite have been extensively worked in the Kongsberg region for Cu and Ag deposits for over five centuries (Bugge, 1917, 1928, 1937; NGU, 1981, 2017). This metamorphic sequence follows the north-south parallel regional 'fahlbands', which are subvertical zones enriched in sulphides of hydrothermal origin (Bugge, 1917, 1928, 1937; Gammon, 1966; Boyle, 1968; Kotková et al., 2018). To the south of Kongsberg, a more sporadic distribution of sulphide deposits has been worked on a

* Corresponding author.

E-mail address: liam.bullock@abdn.ac.uk (L.A. Bullock).

<https://doi.org/10.1016/j.oregeorev.2018.06.023>

Received 26 March 2018; Received in revised form 22 June 2018; Accepted 28 June 2018

Available online 07 July 2018

0169-1368/ Crown Copyright © 2018 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

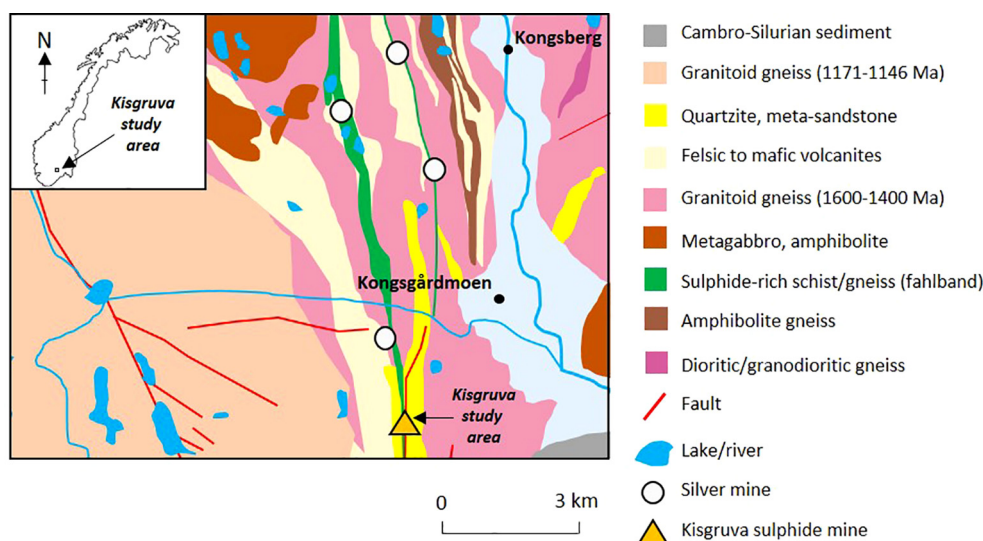


Fig. 1. Geological map and sampling location in the Kisgruva area of the Kongsberg mining region (modified after Viola et al., 2016; Kotková et al., 2018).

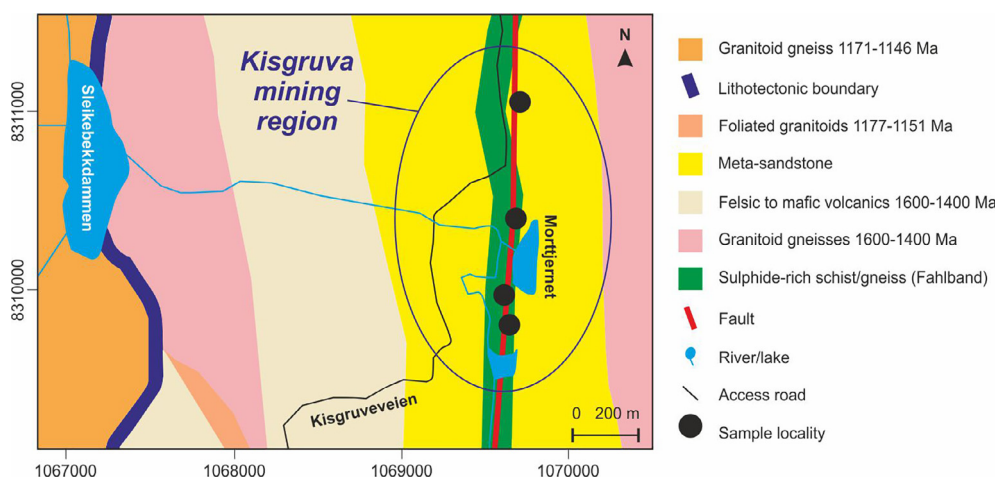


Fig. 2. Sampling sites and local geology in the Kisgruva mining region (modified after Viola et al., 2016; Kotková et al., 2018).

smaller scale, including the Kisgruva deposit (Bugge, 1928; NGU, 1981, 2017; Fig. 1). Former Kisgruva workings are now characterised by exposure of extensively worked sulphide ore deposits, the metamorphic bedrock host and the outermost weathered sulphide ore crust. A potentially key Se (and by chemical association, Te) source in near-surface environments is an oxidation zone of Se and Te-bearing mineral phases, sulphide deposits and associated waste products (Charykova and Krivovichev, 2017), meaning sites such as Kisgruva may host potentially high Se in both primary ore deposits and their weathered derivatives. Secondary formation of Se and Te-bearing mineral phases is caused by active precipitation of aqueous solutions in near-surface conditions within the oxidation zone of sulphide ores, under conditions of seasonal fluctuations of temperatures and atmospheric pressure (~1 bar) (Charykova and Krivovichev, 2017). Elements such as Se and Te may be mobilised under oxidising conditions (Howard, 1977; Northrop and Goldhaber, 1990; Simon et al., 1997; Xiong, 2003; Min et al., 2005; Spinks et al., 2014, 2016), and re-precipitated in the presence of a reducing agent (e.g. carbonaceous materials, sulphides, biogenic H₂S, ferromagnesian minerals; Spinks et al., 2014, 2016). These elements may be co-precipitated with iron oxides and adsorbed from solution (Parnell et al., 2018).

Despite a handful of reports and studies which refer to high Se in the region (NGU, 1981, 2017; Bjerkgård, 2015; Kotková et al., 2018), the mineralogy and trace element geochemistry of Kisgruva sulphide ore

deposits, metamorphic bedrock and weathered ore crust is relatively unknown. Therefore, the aims of this study are to:

- Obtain an overview of Se and Te concentrations in Kisgruva sulphide ore, bedrock and weathered ore crust.
- Identify mineral hosts and speciation of Se and Te at Kisgruva.
- Determine the processes of Se and Te mobility and fixation at Kisgruva.
- Review the economic potential of the Kisgruva site for Se and Te.

Sampled deposits include (1) the mineralised sulphide ore zones, (2) the crystalline metamorphic bedrock host, and (3) the outermost weathered crust of the ore. Sample mineralogy, whole rock Se and Te concentrations and Se and Te speciation were determined for sulphide ore and weathered ore crust deposits. High Se and Te deposits in Kisgruva offer an opportunity to assess the means of occurrence, origins, transport mechanisms and enrichment of these critical elements. Sulphide ores and associated weathered ore crusts at Kisgruva and similar sites former mining sites may provide a key source of Se and Te, important as demand continues to increase worldwide.

2. Historic mining at Kisgruva

The former Kisgruva mine (Figs. 1 and 2) has an estimated 581

Download English Version:

<https://daneshyari.com/en/article/8909483>

Download Persian Version:

<https://daneshyari.com/article/8909483>

[Daneshyari.com](https://daneshyari.com)