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Chapter 24
Muruntau, Uzbekistan: The World's Largest Epigenetic Gold Deposit
Seltmann et al., 2020

Appendices 1-5: Supplementary Data

Appendix 1.

Electronic Supplement ES1: Bibliography of key articles on Muruntau

Appendix 2.

Electronic Supplement ES2:

A. Zircon and monazite U-Pb isochron ages (crystallization ages of granites)

B. Re-Os isochron age of gold-bearing arsenopyrite (age of main mineralization)

Appendix 3.

Electronic Supplement ES3: New Re-Os molybdenite age

Appendix 4.

Electronic Supplement ES4: Sections and 3D model of Muruntau stockwork

(Supplement to Fig. 7)

Appendix 5.

Electronic Supplement ES5: Conceptual models for Muruntau (after Wall et al. 2004)

(Supplement to Fig. 9)

Electronic Supplement ES1: Bibliography of key articles on Muruntau

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Electronic Supplement ES2

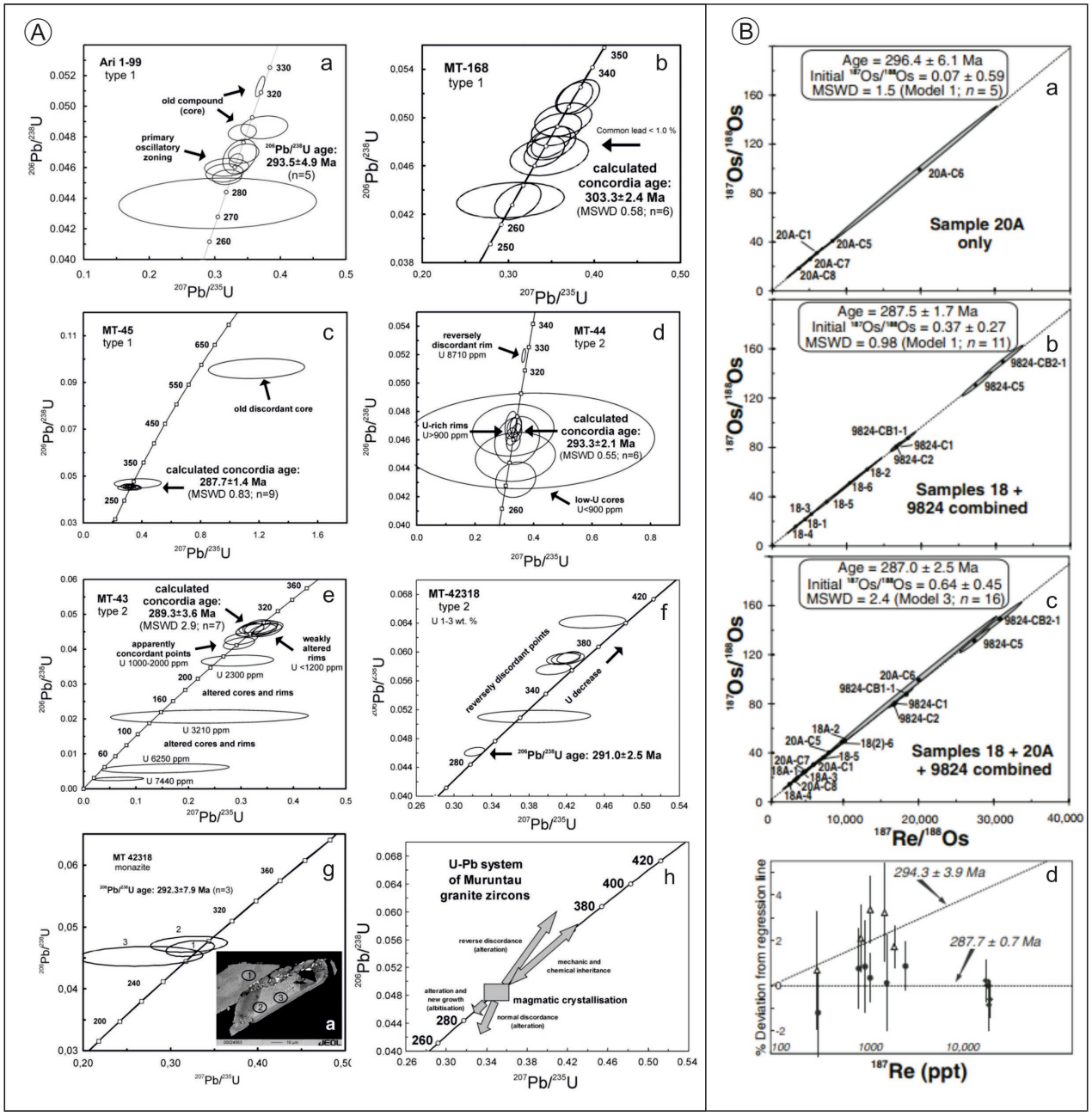

Figure ES 2. Schematic summary diagram illustrating timing of intrusions and mineralization. Zircon and monazite U-Pb isochron ages of intrusive rocks from the Muruntau district (Kempe et al., 2015) in the left column **A**, and arsenopyrite Re-Os isochrons (Morelli et al., 2007) in the right column **B**. The latter represents the age of the main mineralization event, also confirmed by a separate Re-Os molybdenite age (drill core from pit extension at Myutenbay) discussed in Appendix ES 3.

A. U-Pb ages

(a) Results of SHRIMP dating of zircon from sample Ari 1-99 (Aristantau; type 1 in Kempe et al., 2015). Concordia plot of all spots measured. The spots measured in areas with primary oscillatory growth zoning (cf. b) form a coherent group with a calculated $^{206}Pb/^{238}U$ age of 293.5 ± 4.9 Ma (n = 5; lower arrow in a). Spots in core zones with primary and secondary oscillatory zoning (cf. c) yield

$^{206}Pb/^{238}U$ ages above and spots in areas with strong recrystallization (cf. b) yield 206Pb/238U ages below this value.

(b) Results of SHRIMP dating of zircon from sample MT-168 (Muruntau dike, type 1). There is a remarkable scatter in the obtained ages. Calculation with six measurements for common Pb contents below 1% yields a concordia age of 303.3 ± 2.4 Ma. Two strongly discordant points from grain 4 with apparent ages below 260 Ma are not shown. See text for further discussion.

(c) Results of SHRIMP dating of zircon from sample MT-45 (Tamdy; type 1) in the concordia plot. For all but one spots a well-defined concordia age of 287.7 ± 1.4 Ma may be calculated. A discordant core yields a clearly older, strongly discordant age.

(d) Results of SHRIMP dating of zircon from sample MT-44 (Tamdy; type 1) in the concordia plot. Only spots located in areas with U contents above 900 ppm yielded precise data used for calculation of a concordia age of 293.3 ± 2.1 Ma. The point with the highest measured U content of 8710 ppm plots clearly as reversely discordant in the Concordia diagram.

(e) Concordia plot of the results of SHRIMP measurements of zircon from sample MT-43 (Tamdy; type 2). Less altered rims with U contents below 1200 ppm form a coherent group with a related concordia age of 289.3 ± 3.6 Ma. Two apparently concordant points yield significantly younger ages of 271.4 ± 4.3 and 263.1 ± 4.3 Ma ($^{206}Pb/^{238}U$ ages). Data points with U > 2000 ppm plot as strongly discordant.

(f) Concordia plot of the results of SHRIMP measurements of zircon in rock thin section of sample MT-42318 (Murun granite; type 2 in Kempe et al., 2015). Single points plot as increasingly reversely discordant with decreasing U content. The only spot from an area with no signs of alteration (U loss) yields a $^{206}Pb/^{238}U$ age of 291.0 ± 2.5 Ma.

(g) SHRIMP measurements for monazite in sample MT-42318 (Murun granite; type 2). Concordia plot for the three measurements defining a concordia age of 292.3 ± 7.9 Ma. a - Location of the spots in the monazite grains. Note alteration features in the monazite.

(h) Model for interpretation of observed variations in the U–Pb isotope systematics of accessory zircon from granitoid rocks in the Muruntau area. See Kempe et al. (2015) for further discussion.

B. Re-Os ages

(a) Re-Os model 1 isochron from regression of analyses of Muruntau arsenopyrite sample 20A (from Morelli et al., 2007).

(b) Re-Os model 1 isochron from regression of analyses of arsenopyrite samples 18 and 9824 from Muruntau. Age quoted is from $^{187}Re/^{188}Os$ versus $^{187}Os/^{188}Os$ regression.

(c) Re-Os model 3 “errorchron” from regression of analyses of all arsenopyrite samples from Muruntau (9824 + 18 + 20A).

(d) Re-Os ages derived from regression of analyses of independent arsenopyrite samples in ^{187}Re versus $^{187}Os^*$ (radiogenic Os) space. This plot reveals deviations outside 2σ uncertainties of analyses of sample 20A (open triangles), which individually yield a model 1 age of 294.3 ± 3.9 Ma, from regression line defined by samples 18 (filled circles) and 9824 (filled diamonds).

Regression of all data in this study was performed using Isoplot version 3 (Ludwig, 2003). MSWD - mean square of weighted deviates. For Re-Os analytical methods see Morelli et al. (2007).

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Electronic Supplement ES3

Table ES3. Re-Os dating of molybdenite from a molybdenite vein in drill core, Myutenbai.

Sample ID	Re ppm	+/-2σ absolute	187Re ppm	+/-2σ absolute	187Os ppb	+/-2σ absolute	Total common Os	Model age Ma	+/-2σ absolute
Myuten-bai Mb-1	30.35	0.10	19.07	0.06	91.84	0.07	4.3	**288.3**	**1.3**

* Analysis by: Crustal Re-Os Geochronology Laboratory at University of Alberta, Canada (Prof. R.A. Creaser).

Sample characterization *Myutenbai Mb-1*: a 5 mm thick streak of molybdenite in drill core (core sampled at depth 881m). Host rock is metasomatite of light beige colour and its mineralogy is comprising orthoclase, sericitized oligoclase, quartz, chloritized and carbonatized biotite, muscovite, streaky calcite, pyrite impregnations.

Re-Os analysis methods for Re-Os molybdenite dating of sample Mb-1

Methods used for molybdenite analysis are described in detail by Selby and Creaser (2004). The sample was processed by metal-free milling and grinding, followed by density and magnetic methods to produce a molybdenite concentrate. The ^{187}Re and ^{187}Os concentrations in molybdenite were determined by isotope dilution mass spectrometry using Carius-tube, solvent extraction, anion chromatography and negative thermal ionization mass spectrometry techniques. For this work, a mixed double spike containing known amounts of isotopically enriched ^{185}Re, ^{190}Os, and ^{188}Os analysis was used (Markey et al., 2007). Isotopic analysis was made using a Micromass Sector 54 mass spectrometer by Faraday collector. Total procedural blanks for Re and Os are less than <3 picograms and 0.5 picograms (<20 fg ^{187}Os), respectively. These procedural blanks are insignificant in comparison to the Re and Os concentrations in molybdenite. The molybdenite powder HLP-5 (Markey et al., 1998) was analyzed at the same time and yielded a Re-Os date of 220.0 ± 1.0 Ma. This Re-Os age date is indistinguishable to that reported by Markey et al. (1998) of 221.0 ± 1.0 Ma.

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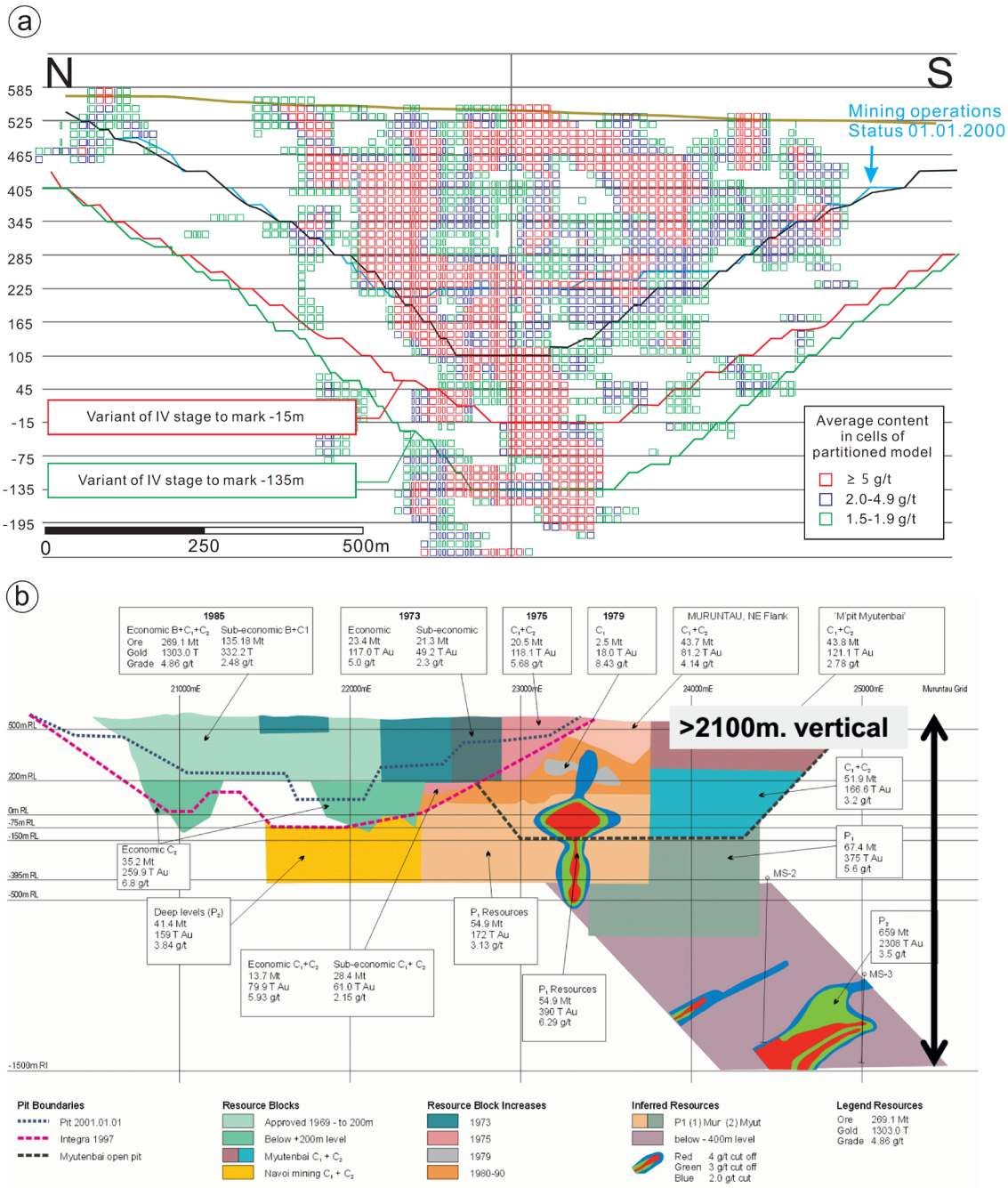
Electronic Supplement ES4

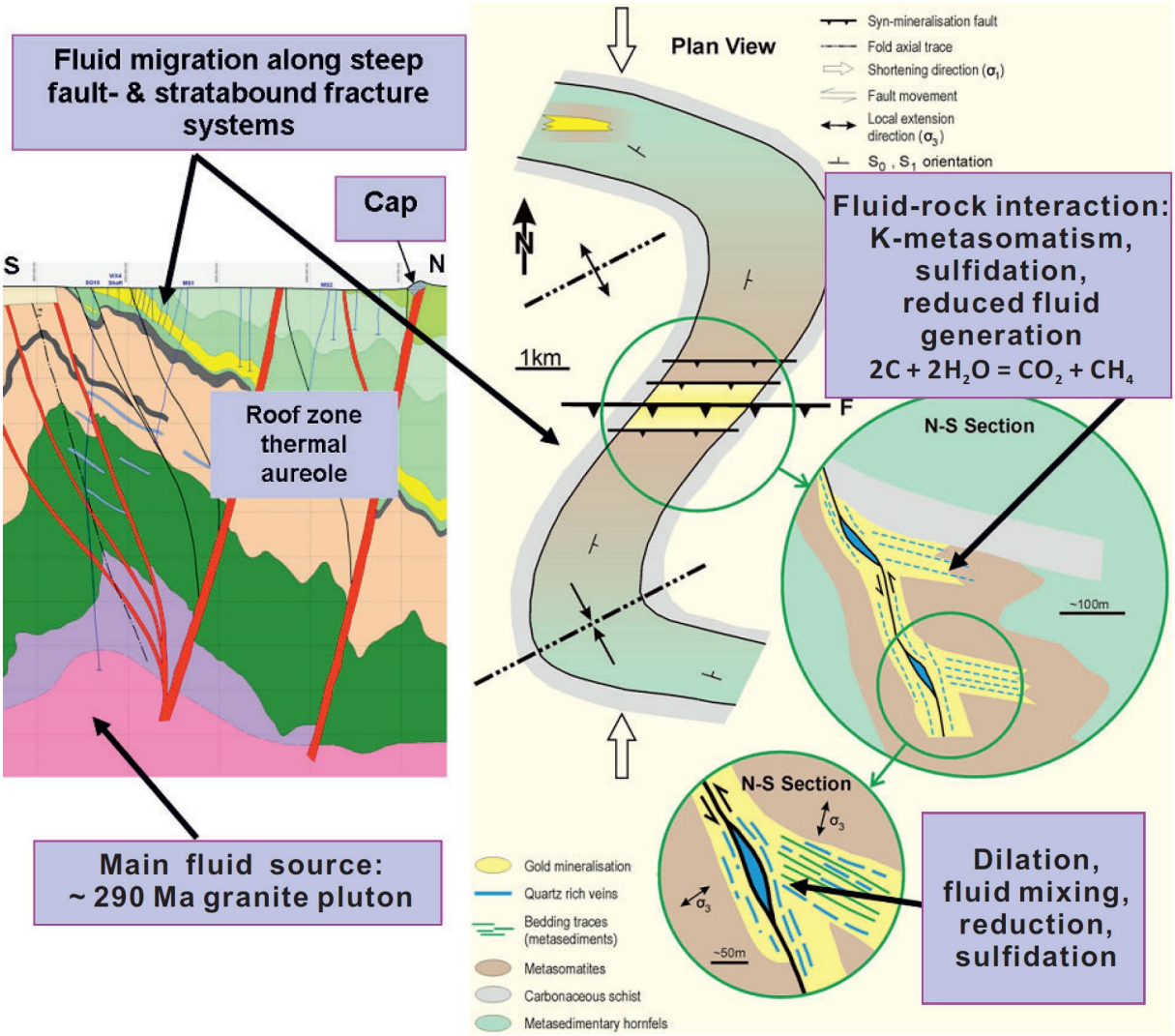


ES to Fig. 7. Sections and 3D model of Muruntau stockwork.

ES4a. Partitioned model of deposit plotted for sampling data of detailed exploration drifts. Gold grade distribution from NMMC-INTEGRA block model for Muruntau, Section B-B (Section 113; from Kuchersky et al., 2002). Higher Au grade zones steeply to moderately dipping to S and shallowly to S-SE. The >5 g/t grade contour shows the steep fluid conduit and some secondary shallow flat veins in reactive horizons with favorable permeability.

ES4b. Grade blocks, Longitudinal projection of Muruntau and Myutenbai resources. NMMC stated 01.01.2003 reserves as 841 Mt of ore for 1731T (55.65 Moz) Au, (2.06 g/t Au) or >150 Moz Au resources @1-2 g/t Au cut-off. Redrafted from NMMC poster, Tashkent, October 2003.

Electronic Supplement ES5



ES to Fig. 9. Conceptual models for Muruntau.

ES5. Conceptual model of thermal aureole gold (TAG) system of Muruntau (Wall et al., 2004). The insert boxes in the cartoon highlight key factors in the localization and size of the deposit. The main structural control and fluid conduit is provided by a district-scale block uplift hosting the ~290 Ma granite pluton surrounded by hornfels and thermal aureole in its roof zone, enabling fluid migration along steep fault- and stratabound fracture systems. In deposit scale, dilation aids tectonic pumping with fluid mixing and fluid-rock interaction (K-metasomatism, sulfidation, generation of reduced fluids).