

Review

Physicochemical Parameters and Geochemical Features of Ore-Forming Fluids for Orogenic Gold Deposits Throughout Geological Time

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Abstract: This paper reviews data from numerous publications focused on the physicochemical parameters and chemical composition of ore-forming fluids from orogenic gold deposits formed during various geological epochs. The paper presents analysis of the distribution of the principal parameters of mineralizing fluids depending on the age of the mineralization. Some parameters of the fluids (their salinity and pressure) at orogenic gold deposits are demonstrated to systematically vary from older (median salinity 6.1 wt.%, median pressure 1680 bar) to younger (median salinity 3.6 wt.%, median pressure 1305 bar) deposits. The detected statistically significant differences between some parameters of mineralizing fluids at orogenic gold deposits are principally new information. The parameters at which mineralization of various age was formed are demonstrated to pertain to different depth levels of similar mineralization-forming systems. The fluid parameters of the most ancient deposits (which are mostly deeply eroded) correspond to the deepest levels of orogenic fluid systems. Hence, the detected differences in the salinity and pressure of the mineralizing fluids at orogenic deposits of different age reflect the vertical zoning of the mineralizing fluid systems.

Keywords: orogenic gold deposit; mineralizing fluid; fluid inclusions; temperature; salinity; pressure; age; zonation

1. Introduction

Orogenic gold deposits are one of the world's main groups of gold deposits that provide a source of gold ([1], etc.). Deposits of this class are formed in deformed and metamorphosed crustal blocks and terranes, typically in greenschist facies rocks adjacent to major crustal fault zones. Orogenic gold deposits were generated during a time span of more than 3 byr, from the Precambrian throughout the whole Phanerozoic [2]. It is thus interesting to understand how, and how much, the fluid regime (i.e., the physicochemical parameters and chemical composition of mineral-forming fluids) evolved over the Earth's history when these deposits were formed.

To do this, we examined a database [3] that currently contains data compiled from a large quantity of publications on mineral-hosted fluid inclusions. Before these data were entered into the database, we tested them for suitability and reliability. Data on mineral-hosted fluid inclusions from gold deposits have been reported extensively in the economic geology literature during the past four to five decades. This information includes estimates of the composition and P–T parameters of the mineral-forming fluids, but also the age of the ore-forming processes. We analyzed these parameters in the database, as well as associated information on the volatile composition of orogenic gold-forming fluids for which

reliable isotopic or geological age data were available. We have gathered information on more than 300 orogenic gold deposits of different age from 186 publications (Table 1), which illustrates how informative are our data on the physicochemical parameters of fluids for the whole class of orogenic gold deposits. More than 3500 conjugated estimations of homogenization temperatures and fluid salinities and more than 1100 conjugated estimations of temperatures and pressures are collected. Tables 2–7 provides information on the range of variations in fluid temperatures, salinity and pressures, the number of inclusions studied, and the chemical composition of the fluid. The deposits discussed herein (Table 1) were subdivided into the following five age groups: Meso-Neoproterozoic (3200–2500 Ma), Paleoproterozoic (2500–1600 Ma), Meso- and Neoproterozoic (1600–540 Ma), Paleozoic (540–250 Ma), Mesozoic (250–65 Ma), and Cenozoic (65–0 Ma). It is necessary to mention that data on Neo- and Mesoproterozoic gold deposits are relatively scarce; hence, we were not able to analyze this time span in more detail.

The parameters for the PTX of the fluids in the comprehensive database are for individual samples, if this information is available from the respective papers. In cases where many values for inclusion homogenization temperatures were reported for a given sample, the database presents an average value for the sample if the difference between the maximum and minimum temperature values is less than 50 °C. If this difference is equal to or greater than 50 °C, then both the maximum and the minimum temperature values are reported. Analogously, for the salinity measurements, we assume average values if the difference is less than 5 wt.% and use the maximum and minimum values if the difference is greater. For fluid pressure, average values are used if the difference is smaller than 10%, and, otherwise, the maximum and minimum values are reported.

Some publications on multiphase fluid inclusions containing saturated chloride brines quote homogenization temperatures as those when the gas bubble dissolved in the inclusion, despite the halite phase dissolving at a higher temperature. Because salinities in these inclusions were calculated from the NaCl solubility relationships, in the publications lacking reported halite dissolution temperatures, these data fall behind the saturation curve of aqueous solution with sodium chloride. To transform information on such inclusions into a reasonably accurate form, we quote their homogenization temperatures as the calculated homogenization temperatures of a saturated NaCl solution whose concentration is as specified in the paper.

2. Brief Description of the Deposits

For our analysis, we have selected deposits at which the arrangement of mineralized veins is controlled by tectonics. These are mostly deposits hosted in sedimentary or metamorphic rocks. The deposit was included in the sample if its geological characteristics did not contradict to the attributes of orogenic gold deposits formulated in the classical work [4]. In controversial cases, we included a deposit in the number of orogenic ones if it was considered orogenic in the review works of authoritative scientists, for example [5]. The resources and reserves of these deposits broadly vary from small (<10 tonnes) to superlarge (>1000 tonnes). In Table 1, deposits printed in bold face have gold reserves of 100 tonnes or more, and data for these were analyzed separately to determine what fluid parameters, if any, led to formation of such large deposits. Deposits data on which are absent from Table 1 are small- and medium-sized ones.

The evaluated gold deposits are listed in Table 1 in ascending order of their age (e.g., from younger to older) and, within a given epoch, in the chronological order of the publications, with data on the parameters and composition of the fluids.

Among the **Cenozoic** deposits, we discuss those in the United States, Canada, Italy, Austria, New Zealand, China, Iran, Georgia Republic, and Mexico. The data were compiled from nineteen publications and pertain to 26 gold deposits. Some of these deposits are large: Alaska-Juneau (USA), Bralorne-Pioneer (Canada), La Herradura (Mexico), and Daping (China).

The **Mesozoic** deposits are located in the United States, China, Korea, New Zealand, Russia, Mongolia, and Honduras. The data were borrowed from 70 publications and characterize

155 gold deposits. Among these, the following deposits are large: Samdong and Gubong (Korea), Dongping, Linglong, Wenyu, Sanshandao, Dongfeng, Taishang, Luoshan, and Jinshan (China), Kyuchus, Mayskoye, Nezhdaninskoye, Arkachan, Natalkinskoye (Russia), and Donlin Creek (USA).

The **Paleozoic** deposits occur in Australia, Kazakhstan, Peru, Russia, Uzbekistan, France, and Portugal. The data are from 33 publications and characterize 53 gold deposits. The large deposits are Zholymbet, Bestobe, S. Aksu, and Vasilkovskoye, (Kazakhstan), Zarmitan (Uzbekistan), Sukhoi Log, Verninskoye and Berezovskoye (Russia), and Bendigo, Charters Towers, and Telfer (Australia).

The **Meso- and Neoproterozoic** deposits are known in Russia, Brazil, Sweden, Australia. The data were extracted from seven publications and characterize twelve gold deposits. The large deposits among these are Olimpiadinskoye and Veduga (Russia), and Telfer (Australia).

The **Paleoproterozoic** deposits are known in Canada, Finland, Brazil, Australia, Sweden, West Africa, Mali, and Ghana. The data were collected from 22 publications and characterize 29 gold deposits. The large deposits among these are Callie (Australia), Morila and Yalea (Mali), and Piaba (Brazil).

Meso-Neoproterozoic deposits of this type are known in Canada, India, South Africa, Australia, Finland, and Zimbabwe. The data were taken from 33 publications and pertain to 35 gold deposits. The large deposits include McIntyre-Hollinger, Sigma, Pamour, Surluga, and Giant (Canada), Kolar, Hutti, Uti, and Hira-Buddini (India), and Wiluna, Junction, Golden Mile/Mount Charlotte, and Tarmoola (Australia).

Note that many of these deposits are world-class gold deposits with >100 tonnes Au. These giants include the ore fields of Kolar, India; Telfer, Bendigo, and Kalgoorlie, Australia; McIntyre-Hollinger, Canada; Vasilkovskoye, Zarmitan, Muruntau, and Kumtor, Central, Asia; Sanshandao and Linglong, China; and Natalkinskoye, Olimpiadinskoye, and Sukhoi Log, Russia.

Table 1. Orogenic gold deposit.

Deposition *, Country	Province	Gold Content, Moz (Million Ounces)	Gold Content, Metric Tons	Age, Ma	Reference
Cenozoic					
Valdez Group, USA	South-central Alaska	0.26	8	50–55	[6]
Venus, Canada	Yukon Territory	<0.16	<5	70	[7]
Monte Rosa gold district, Italy	Northwestern Alps	0.5	15	20	[8]
Fairview, Oro Fino, Canada	Okanagan Valley, British Columbia	2.2	68	Tertiary	[9]
Twin Lakes, Canada	Okanagan Valley, British Columbia	0.01	0.27	Tertiary	[9]
Alaska-Juneau, USA	Juneau Gold Belt, Alaska	3.4	106	55	[10]
Ibex, USA	Juneau Gold Belt, Alaska	<0.3	<10	55	[10]
Reagan, USA	Juneau Gold Belt, Alaska	<0.3	<10	55	[10]
Treadwell, USA	Juneau Gold Belt, Alaska	3.1	96	55	[10]
Bralorne-Pioneer, Canada	British Columbia	4.1	129	65	[11]
Monte Rosa gold district, Italy	Northwestern Alps	0.5	15	24–32	[12]
Bralorne-Pioneer, Canada	British Columbia	4.1	129	65	[13]
Callery, New Zealand	BDT	<0.16	<5	Quaternary	[14]
Shotover, New Zealand		<0.16	<5	Miocene	[14]
Mt. Alta, New Zealand		<0.16	<5	Miocene	[14]
Nenthorn, New Zealand		<0.16	<5	Paleocene–Eocene	[14]
Böckstein, Austria	Northwestern Alps	<0.16	<5	Tertiary	[15]
Monte Rosa gold district, Italy	Northwestern Alps	0.5	15	24–32	[15]
Kensington, USA	Berners Bay District, Southeast Alaska	1.9	60	55	[16]
Jualin, USA	Berners Bay District, Southeast Alaska	0.3	9	55	[16]
Shannan area China	S. Tibet	0.96	30	Eocene	[17]
Muteh, Iran	Zagros	0.45	14	38.5–55.7	[18]
Zopkhito, Georgia Republic	Greater Caucasus	1.8	55	4–5	[19]
La Herradura, Mexico	Northwestern Mexico	5.4	168	61.0 ± 2.1	[20]
Daping, China	Yunnan Province	>4.8	>150	Cenozoic	[21]
Mayum, China	Tibet	>2.6	>80	59	[22]
Zhemulang, China	Lang County, Tibet	<0.16	<5	12–35	[23]
Mazhala, China	Cuomei County, Tibet	<0.16	<5	12–35	[23]
Qolqoleh, Iran	Sanandaj–Sirjan Zone, Kurdistan Province	<0.3	<10	Early Tertiary	[24]
Bangbu, China	Southern Tibet	1.3	40	Cenozoic	[25]
Mezozoic					
Oriental mine, USA	California	0.15	4.7	120	[26]
Big Hurrah, USA	Alaska	<0.3	<1	110	[27]
Mouthier Lode, USA	California	1.7	53	125	[28]
Yata, China	Guizhou, Youjiang basin, S. China	0.32	10	182–206	[29]
Daeil, Korea	Youngdong dist.	-	-	145	[30]
Macraes, New Zealand		-	-	Cretaceous	[14]

Table 1. Cont.

Deposition *, Country	Province	Gold Content, Moz (Million Ounces)	Gold Content, Metric Tons	Age, Ma	Reference
Mezozoic					
Glenorchy, New Zealand		-	-	Cretaceous	[14]
Barewood, New Zealand		-	-	Cretaceous	[14]
Bendigo, New Zealand		-	-	Cretaceous	[14]
Bonanza, New Zealand		-	-	Cretaceous	[14]
Quartz Hill, USA	California	0.1	3.7	150	[31]
Lover Dominion, Canada	Klondike, Yukon Territory	-	-	160	[32]
Aime, Canada	Klondike, Yukon Territory	-	-	160	[32]
Gold Run, Canada	Klondike, Yukon Territory	-	-	160	[32]
Portland Creek, Canada	Klondike, Yukon Territory	-	-	160	[32]
Lloid, Canada	Klondike, Yukon Territory	-	-	160	[32]
Hunker Dome, Canada	Klondike, Yukon Territory	-	-	160	[32]
Mitchell, Canada	Klondike, Yukon Territory	-	-	160	[32]
Sheba, Canada	Klondike, Yukon Territory	2.2	69	160	[32]
Lone Star, Canada	Klondike, Yukon Territory	-	-	160	[32]
Hilchey, Canada	Klondike, Yukon Territory	-	-	160	[32]
27 Pup, Canada	Klondike, Yukon Territory	-	-	160	[32]
Violet, Canada	Klondike, Yukon Territory	-	-	160	[32]
Virgin, Canada	Klondike, Yukon Territory	-	-	160	[32]
Amethyst, Canada	Klondike, Yukon Territory	-	-	160	[32]
Samdong, Korea	Youngdong mining district, Korea	4.2	132.4	Jurassic	[33]
Barneys Canyon, USA	Utah	0.45	14	147–159	[34]
Mouse Pass, USA	Alaska	-	-	95–110	[35]
Nuka Bay, USA	Alaska	-	-	95–110	[35]
Chichago mine, USA	Alaska	-	-	95–110	[35]
Berners Bay, USA	Alaska	-	-	95–110	[35]
Alaska-Juneau mine, USA	Alaska	-	-	95–110	[35]
Treadwell mine, USA	Alaska	-	-	95–110	[35]
Sumdum Chief mine, USA	Alaska	-	-	95–110	[35]
Willow Creek, USA	Alaska	-	-	95–110	[35]
Valdez Creek, USA	Alaska	-	-	95–110	[35]
Fairbanks, USA	Alaska	-	-	95–110	[35]
Ryan Lode, USA	Alaska	-	-	95–110	[35]
Fort Knox, USA	Alaska	1.4	45	95–110	[35]
Table Mountain, USA	Alaska	-	-	95–110	[35]
Rock Creek, USA	Alaska	-	-	95–110	[35]
Chandalar, USA	Alaska	-	-	95–110	[35]
Dongping, China	Hebei province	>3.2	>100	153	[36]
Niuxinshan, China	E. Hebei, NE China	0.6	20	166	[37]
Hanshan, China	NW China	1.9	60	214–224	[38]
Kyuchus, Russia	Sakha-Yakutia	5	157	Late Cretaceous	[39]
Svetloye, Russia	Sakha-Yakutia	-	-	Mesozoic	[39]
Tas-Uryakhskoye, Russia	Khabarovsk	1.3	40	Cretaceous	[39]
Baidi, China	China	-	-	75–140	[40]
Banqi, China	Youjiang basin China	0.3	10	182–206	[40]
Dongbeizhai, China	China	2.25	70	Middle Jurassic	[40]
Gaolong, China	China	0.8	25	182–206	[40]
Gedang, China	China	0.2	7	182–206	[40]
Jinya, China	South China platform	1	30	Cretaceous	[40]
Lannigou, China	South China platform	2.6	80	182–206	[40]
Mingshan, China		0.3	10	182–206	[40]
Shijia, China		0.3	10	75–140	[40]
Humboldt, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Dun Glen, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Santa Rose, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Ten Mile, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Eugene, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Slumbering, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Antelope, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Trinity, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Pine Forest, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Pueblo, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Jackson, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Quinn River, USA	Northwestern Nevada	-	-	Cretaceous	[41]
Wangu China	Hunan province	0.4	13	70	[42]
Kuzhubao and Bashishan China	Yunnan Province, Fu Ning district	-	-	Mesozoic?	[43]
Sanshandao, China	North China platform, Jiaodong province	3.4	107	Early Cretaceous	[44]
Dongping, China	Hebei province,	3.2	100	153	[45]
Donlin Creek, USA	Northern Alaska	24.7	770	70	[46]
Mayskoye, Russia	Chukchi peninsula	3.6	114	107–115	[47]
Anjiayingzi, China	North China Craton	1.1	35	Mesozoic	[48]
Paishanlou, China	North China Craton	1.3	40	124–126	[49]
Denggezhuang, China	Muru Gold Belt in Eastern Shandong	1.4	44	Mesozoic	[50]
Gubong, Korea	Cheongyang gold district, Cheonan metallogenic province	4.8	150	Early Cretaceous	[51]
Rushan, China	Jiaodong Peninsula	>1	>30	117	[52]
Bajintazi, China	Daduhe field, Tibetan Plateau	0.04	1.2	Mesozoic	[53]
Heijintazi, China	Daduhe field, Tibetan plateau	0.05	1.5	Mesozoic	[53]
Nezhdaninskoye, Russia	Sakha-Yakutia	3.6	114	115–124	[54]
Linglong, China	Shandong Province	4	124	Early Cretaceous	[55]

Table 1. Cont.

Deposition *, Country	Province	Gold Content, Moz (Million Ounces)	Gold Content, Metric Tons	Age, Ma	Reference
	Mezozoic				
Sarylakh, Russia	Sakha-Yakutia	1.3	40	124	[56]
Sentachan, Russia	Sakha-Yakutia	0.6	20	Early Cretaceous	[56]
Dyby, Russia	NE Russia	0.96	30	125	[57]
Ergelyakh 1, Russia	NE Russia	0.1	3	140–149	[57]
Ergelyakh 2, Russia	NE Russia	0.1	3	140–149	[57]
Ergelyakh 3, Russia	NE Russia	0.1	3	140–149	[57]
Arkachan, Russia	W. Verkhoyanye	3.2	100	Mesozoic	[57]
Kimpichenskoye, Russia	W. Verkhoyanye	-	-	Mesozoic	[58]
Arkachan, Russia	W. Verkhoyanye	3.2	100	Mesozoic	[58]
Natalkinskoye, Russia	NE Russia	3.2	100	135	[59]
Rodionovskoye, Russia	NE Russia	0.06	2	Early Cretaceous	[60]
Shuiyindong, China	Guizhou, Youjiang basin	1.8	55	182–206	[61]
Yata, China	Guizhou, Youjiang basin, S. China	0.32	10	182–206	[61]
Samgwang, Korea	Korea	2.3	72	127	[62]
Sentachan, Russia	Sakha-Yakutia	0.6	20	Early Cretaceous	[63]
Sarylakh, Russia	Sakha-Yakutia	1.3	40	Early Cretaceous	[63]
Guodawa, Songweizi, Tonggoucheng and Xiaomiaoshan, China	Zhangbaling Tectonic belt	-	-	116–118	[64]
Shkolnoye, Russia	NE Russia	0.06	2	135	[65]
Badran, Russia	Sakha-Yakutia	0.45	14	Mesozoic?	[66]
Pogromnoye, Russia	Transbaykalia	1.6	50	Late Jurassic	[67]
Wenyu, China	North China Platform	>3.2	> 100	127	[68]
Banqi, China	Youjiang basin	0.32	10	182–206	[69]
Bojitian, China	Youjiang basin S. China	0.5	15	182–206	[69]
Lannigou, China	South China platform	2.5	80	182–206	[69]
Shuiyindong, China	Guizhou, Youjiang basin	1.8	55	182–206	[69]
Taipingdong, China	Youjiang basin	1.8	57	182–206	[69]
Yata, China	Guizhou, Youjiang basin, S. China	0.5	15	182–206	[69]
Zimudang, China	Youjiang basin, S. China	1.9	60	182–206	[69]
Yangzhaiyu, China	North China Craton	1.1	34	124–141	[70]
Qianhe, China	Xiong'ershan area, North China Craton	-	-	124–135	[71]
Sanshandao, China	Jiaodong Peninsula, Shandong province	3.4	107	Early Cretaceous	[72]
Jinshan, China	between the Yangtze and Cathaysia blocks, South China	3.4	107	Mesozoic?	[73]
Gatsuurt, Mongolia	North Khentei Gold Belt, Central N Mongolia	<1.6	<50?	178	[74]
Taipingdong, China	Huijiabao gold district, Yangtze craton	1.8	57	182–206	[75]
Zimudang, China	Huijiabao gold district, Yangtze craton	1.9	60	182–206	[75]
Shuiyindong, China	Huijiabao gold district, Yangtze craton	1.8	55	182–206	[75]
Bojitian, China	Huijiabao gold district, Yangtze craton	0.5	15	182–206	[75]
Wenyu, China	North China Platform	>3.2	> 100	127	[76]
Sanshandao, China	Jiaodong gold province	3.4	107	117.6 ± 3	[77]
Arkachan, Russia	W. Verkhoyanye	3.2	100	Mesozoic Late	[78]
Canan area, Honduras	Lepaguare District, Central America	-	-	Cretaceous–Early Tertiary	[79]
Zhaishang, China	Min–Li metallogenic belt, W Qinling Mountains	>9.6	> 300	220	[80]
Qiangma, China	North China Craton	>0.6	>20	130	[81]
Dongfeng, China		5.1	158	125	[82]
Linglong, China		4	124	125	[82]
Erdaogou, Xiaobeigou, China	Jiapigou gold province, NE China	>3.2	> 100	219–228	[83]
Sanshandao, China	Jiaodong gold province	3.4	107	117.6 ± 3	[84]
Anjiayingzi, China	North China Craton	1.1	35	Mesozoic	[85]
Nancha, China	S. Jilin Province, northeast China	0.6	20	Mesozoic	[86]
Taishang, China	Jiaodong Peninsula, eastern China	32	1000	150–165	[87]
Jinchangyu, China	North China Craton	1.6	50	219–233	[88]
Hetai, China	Hetai goldfield, Bay–Hangzhou Bay metallogenic belt	<0.32	<10	Mesozoic	[89]
Liyuan, China	Central North China Craton	<1	<30	125	[90]
Baolun, China	Hainan Province of South China	0.6	20	224–228	[91]
Gezhen, China	Hainan Province of South China	-	-	224–228	[91]
Dongping, China	Hebei province	>3.2	> 100	153	[92]
Xadian, China	Jiaodong Peninsula	0.5	14.6	120–126	[93]
Luoshan, China	Jiaodong peninsula	4.8	149	125	[94]
Fushan, China	Jiaodong peninsula	0.5	15	125	[94]
Bake, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Chanziping, China	Jiangnan Orogenic Belt, Yangtze Block	0.68	21	130–144	[95]
Dagaowu, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Fenshuiao, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Gaokeng, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Hamashi, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Huangjindong, China	Jiangnan Orogenic Belt, Yangtze Block	2.6	80	130–144	[95]
Huangshan, China	Jiangnan Orogenic Belt, Yangtze Block	0.96	30	130–144	[95]

Table 1. Cont.

Deposition *, Country	Province	Gold Content, Moz (Million Ounces)	Gold Content, Metric Tons	Age, Ma	Reference
Mezozoic					
Huangtudian, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Jinshan, China	Jiangnan Orogenic Belt, Yangtze Block	9.6	300	130–144	[95]
Kengtou, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Miaoxiafan, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Mobin, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Pingshui, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Taojinchong, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Tonggu, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Tongshulin, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Wangu, China	Jiangnan Orogenic Belt, Yangtze Block	2.7	85	130–144	[95]
Xi'an, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Xichong, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Xintang, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Yanghanwu, China	Jiangnan Orogenic Belt, Yangtze Block	-	-	130–144	[95]
Paleozoic					
Hill End goldfield, Australia	New S. Wales	1.8	56	Early Carboniferous?	[96]
Haut Allier, France	Massif Central	<0.16	<5	260	[97]
Kvartsytovye gorki, Kazakhstan	N. Kazakhstan	0.3	10	Late Ordovician?	[98]
Zholymbet, Kazakhstan	NW. Kazakhstan	7.7	240	Late Ordovician?	[98]
Bestobe, Kazakhstan	NW. Kazakhstan	9.6	300	Late Ordovician?	[98]
N. Aksu, Kazakhstan	NW. Kazakhstan	0.16	5	Late Ordovician?	[98]
S. Aksu, Kazakhstan	NW. Kazakhstan	14.5	450	Late Ordovician?	[98]
Stepnyak, Kazakhstan	NW. Kazakhstan	0.3	10	Late Ordovician?	[98]
Zhana-Tyube, Kazakhstan	NW. Kazakhstan	0.3	10	Late Ordovician?	[98]
Flying Pig, Australia	Hodgkinson field	0.02	0.5	Carboniferous	[99]
Tyrconnel, Australia	Hodgkinson field	0.06	2	Carboniferous	[99]
Pataz district, Peru		0.02?	0.5?	305–321	[100]
Saralinskoye, Russia	Kuznetsk Alatau	0.7	22	Early to Late Silurian	[101]
Nagambie, Australia	Victoria	0.2	7	Silurian–Early Devonian	[102]
Kommunar, Russia	Kuznetsk Alatau	1.6	49	Silurian	[103]
Zarmitan, Uzbekistan	South Tien Shan	16	500	Syn- to post-Late Carboniferous	[104]
Central and North Deborah, Australia		0.2	7	Late Ordovician–middle Silurian	[105]
Sukhoi log, Russia	Bodaybo	48	1500	Paleozoic	[106]
Berezovskoye, Russia	Ural	15	466	Early Silurian	[107]
Fosterville, Australia	Victoria	0.16	5	Devonian	[108]
Vorontsovskoye, Russia	Ural	2.2	68	Late Devonian to Late Carboniferous	[39]
Biards district, France	Massif Central	0.13	4	300–305	[109]
Mayskoye, Russia	N. Karelia	<0.03	<1	397 ± 15	[110]
CSA Cobar, Australia	Cobar	2.6	83	Devonian	[111]
Moulin de Cheni, France	Saint-Yrieix district Massif Central	0.8	24	338	[112]
Jiapigou, China	S. Jilin Province,	1.9	60	Paleozoic?	[113]
Bulong, China	Akqi County, Southwest Tianshan	0.03	1	258	[114]
Charters Tauers goldfield, Australia	Tasman Fold Belt, Quinsleend	6.6	207	Early Devonian?	[115]
Sarekoubu, China	southern Altai, Xinjiang	<0.16	<5	320.6 ± 4	[116]
Qingshui, China	N. Xinjiang	<0.16	<5	315 ± 18	[117]
Tanjianshan, China	W. China	2.3	73.9	269–288	[118]
Sandwich Point, Canada	Sandwich Point Meguma Terrane, Nova Scotia	0.05	1.6	380	[119]
Fosterville, Australia	Victoria	0.16	5	Devonian	[120]
Maldon, Australia	Victoria	1.8	56	445	[120]
Stawell–Magdala, Australia	Victoria	3.3	105	Ordovician	[120]
Bendigo, Australia	Victoria	17.1	533	Ordovician–Silurian	[120]
Wattle Gully, Australia	Victoria	0.4	12.9	Ordovician	[120]
Mount Piper, Australia	Victoria	<0.16	<5	Devonian	[120]
Woods Point, Australia	Victoria	0.9	28	Devonian	[120]
Walhalla (Cohen's Reef), Australia	Victoria	1.5	46	Devonian	[120]
Bogunayskoye, Russia	Enisey ridge	1.9	59	Paleozoic?	[121]
Annage, China	Qinghai Province, Kunlun orogenic belt	<0.16	<5	Paleozoic?	[122]
Woxi, China	Hunan Province	1.35	42	Paleozoic	[123]
Huangshan, China	Jiangshan-Shaoxing fault zone, South China	0.3	10	397 ± 34	[124]
Yingchengzi, China	Southern Heilongjiang Province, NE China	<0.16	<5	434–472	[125]
Limarinho, Portugal	northern Portugal, Variscan Iberian Massif	<0.16	<5	310–315	[126]
Vasil'kovskoe, Kazakhstan		12.2	380	312–279	[127]
Woxi, China	Hunan Province, Jiangnan Orogenic Belt, Yangtze Block	>1.3	>40	Paleozoic	[95]
Sukoy Log, Russia	Baikal–Patom	48	1500	Paleozoic	[128]
Verninskoye, Russia	Baikal–Patom	5.8	180	Paleozoic	[128]
Dogaldyn, Russia	Baikal–Patom	0.6	18	Paleozoic	[128]
Uryakh, Russia	Baikal–Muya	1.8	56	Paleozoic	[128]
Irokinda, Russia	Baikal–Muya	1.9	60	Paleozoic	[128]

Table 1. Cont.

Deposition *, Country	Province	Gold Content, Moz (Million Ounces)	Gold Content, Metric Tons	Age, Ma	Reference
Meso- and Neoproterozoic					
Olimpiadinskoye, Russia	Yenisey fold belt	11.7	365	594	[129]
Cachoeira de Minas, Sao Francisco, Brazil	Borborema Province	<0.3	<10	750	[130]
Veduga, Russia	Yenisey fold belt	4.8	149	600	[131]
Olimpiadinskoye, Russia	Yenisey fold belt	11.7	365	594	[131]
Harnas area, Sweden	Grenville province	0.03	1	1200	[132]
Paio mine, Brazil	Almas Greenstone Belt, Tocantins State	0.6	18	535–702	[133]
Udereyskoye, Russia	Enisey Ridge	0.5	14.7	Proterozoic	[56]
Tunkillia, Nuckulla Hill, Barns, and Weednanna, Australia	Central Gawler Craton	0.7	22	1567–1596	[134]
Tarcoola gold field, S. Australia	Central Gawler Craton	0.7	22.7	1580	[135]
Telfer, Australia	Pilbara	19.0	591	590–640	[136]
Paleoproterozoic					
Tartan Lake, Canada	N. Manitoba	0.1	3	1791	[137]
Star Lake, Canada	La Ronge region, Northern Saskatchewan	0.12	3.9	1848	[138]
Flin Flon Domain, Canada	Trans-Hudson orogeny, Saskatchewan	0.6	19	1791	[139]
Pirila, Finland	Scandinavian	0.04	1.2	1810–1830	[140]
Star Lake (La Ronge), Canada	La Ronge region, Northern Saskatchewan	0.37	11.5	1848	[141]
Caxias, Brazil	Sao Luis craton	0.03	1	1990–2009	[142]
Fazenda Canto, Brazil	Sao Francisco craton, state of Bahia	0.3	10	1800–2200	[143]
Fazenda Maria Preta, Brazil	Sao Francisco craton, state of Bahia	0.5	15	1800–2200	[143]
Fazenda Brasileiro, Brazil	Sao Francisco craton, state of Bahia	2.2	70	1800–2200	[143]
Guarim, Brazil	Tapajos province	<0.3	<10	1880	[144]
Batman, Australia	Burrell Creek Formation	0.3	10	1800–1835	[145]
Serrinha, Brazil	Granite-Related	0.5	15.1	2160	[146]
Callie, Australia	Dead Bullock Soak goldfield	5.8	180	1815–1825	[147]
Coyote Prospect, Australia	Killi Killi Formation	0.45	14	1790–1840	[147]
Groudrust, Australia	Granites goldfield	0.7	22.7	1790–1840	[147]
Tanami gold field, Australia	Mount Charles Formation	1.6	50.9	1790–1840	[147]
Angovia, W. Africa	the Yaoure' area of central Ivory Coast in the West African craton	0.3	10	2050–2250	[148]
Chega Tudo, Brazil	the Gurupi belt of northern Brazil	1.9	60	2000	[149]
Bjorkdal, Sweden	Skellefte District, Northern Sweden	0.6	20	1780–1790	[150]
Carara, Brazil	Guiana Shield	0.3	10	2030	[151]
Morila, Mali	The Birimian schist belts of West Africa	7.0	217	2095–2103	[152]
Loulo 3, Mali	Loulo mining district, Mali, West Africa	1.0	32	Proterozoic	[153]
Gara, Mali	Loulo mining district, Mali, West Africa	3.1	97	Proterozoic	[153]
Yalea, Mali	Loulo mining district, Mali, West Africa	6.3	195	Proterozoic	[153]
Goukoto, Mali	Loulo mining district, Mali, West Africa	-	-	Proterozoic	[153]
Piaba, Brasil	São Luis cratonic fragment	3.9	120	2170–2240	[154]
Turmalina, Brazil	Pitangui Shear Zone, Quadrilátero Ferrífero	1.2	37	1750	[155]
Piaba, Brasil	São Luis cratonic fragment	3.5	109	2227–2240	[156]
Julie, Ghana	The Leo Man Craton in West Africa	1.0	31	1980–2130	[157]
Lamego, Brazil	Rio das Velhas greenstone belt, Quadrilátero Ferrífero	0.4	13	2041	[158]
Meso-Neoproterozoic					
Henderson, Canada	Superior	1.3	42	Late Archaean	[159]
McInture-Hollinger, Canada	Superior, Timmins	31.7	987	2673–2690	[160]
Kolar, India	Dharwar craton	26.9	838	Late Archaean	[161]
Renabie, Canada	Wawa belt, Superior	1.3	40	2722–2728	[162]
Mink Lake, Canada	Superior	<0.03	<1	2730	[163]
Sigma, Canada	Superior	11.5	358	2705	[164]
Kolar, India	Dharwar craton	26.9	838	Late Archaean	[165]
Pamour, Canada	Superior	7.9	247	2703–2725	[166]
Abbotts, South Africa	Barberton	0.004	0.12	3084–3126	[167]
Bellevue, South Africa	Barberton	0.01	0.3	3084–3126	[167]
Pioneer, South Africa	Barberton	0.15	4.55	3084–3126	[167]
Surluga, Canada	Superior	12.4	385	2744	[168]
Sigma, Canada	Superior	11.5	358	2705	[169]
Donalda, Canada	Superior	<1.0	<30	Archaean	[169]
Dumont, Canada	Superior	<0.3	<10	Archaean	[169]
Champion lode, Nundydroog, Kolar, India	Dharwar craton	25.5	794	Late Archaean	[170]
Wiluna, Australia	Yilgarn Block	8.5	265	Archaean	[171]
Bronzewing, Australia	Yilgarn Block	2.7	84	Archaean	[172]
Siscoe, Canada	Superior Abitibi, Ontario	0.9	27	Late Archaean	[173]
Junction, Australia	Yilgarn Block	6.7	209	Archaean	[174]
Golden Eagle, Australia	Mosquito Creek belt, Pilbara Craton	0.4	13.1	2850–2900	[175]
Orenada 2, Cadillac tectonic zone, Canada	Superior	<1.0	<30	2682–2691	[176]
Hutti, India	Dharwar craton	17.1	533	2510–2750	[177]
Golden Crown, Australia	Murchison province, Yilgarn Block	1.1	33.5	2600–2800	[178]
Wiluna, Australia	Wiluna greenstone belt, Yilgarn Block	8.5	265	2749	[179]

Table 1. Cont.

Deposition *, Country	Province	Gold Content, Moz (Million Ounces)	Gold Content, Metric Tons	Age, Ma	Reference
Meso-Neoproterozoic					
Ramepuro, Finland	Ilomantsi greenstone belt, Scandinavian province	0.04	1.25	2700–2750	[180]
Woodcutters field, Australia	Kalgoorlie district, Yilgarn Block	38.6	1200	Archaean	[181]
McPhees, Australia	Pilbara Craton	<0.3	<10	2890–2950	[182]
Tarmoola, Australia	Yilgarn Block	3.7	116	2620–2780	[183]
Mount Charlotte, Australia	Yilgarn Block, Kalgoorlie	4.0	125	Archaean	[184]
Giant, Canada	Slave, Yellowknife greenstone belt	7.9	246	2660–2820	[185]
Uti, India	Dharwar craton	12.9	400	2576	[186]
Primrose, Zimbabwe	Kwekwe district, Midlands greenstone belt, Zimbabwe craton	0.14	4.3	2600–2650	[187]
Jojo, Zimbabwe	Kwekwe district Midlands greenstone belt, Zimbabwe craton	0.02	0.5	2600–2650	[187]
Indarama, Zimbabwe	Kwekwe district Midlands greenstone belt, Zimbabwe craton	0.16	5.1	2600–2650	[187]
Hutti, India	Hutti-Maski greenstone belt, Dharwar craton	>3.2	>100	2532	[188]
Hira-Buddini, India	Hutti-Maski greenstone belt, Dharwar craton	6.4	200	2532	[188]
Sunrise Dam, Australia	Yilgarn Block	1.2	36.7	2670	[189]
Missouri, Australia	Yilgarn Block	0.03	0.9	Archaean	[190]
Klipwal Gold Mine, South Africa	Klipwal Shear Zone, SE Kaapvaal Craton,	0.5	15	2863–2721	[191]

Notes: * In Tables 1–7, deposits printed in bold face have gold reserves of 100 tonnes or more.

3. Characteristics of the Mineralizing Fluids

This section is devoted to characteristics of the fluid regime under which gold deposits of various age groups were formed, with the deposits discussed from youngest to oldest. For each group of deposits, we report the state of the fluids (homogeneous or heterogeneous), brief characteristics of their phases (H₂O–salt solution, dense gas), and the principal parameters of the fluid inclusions (homogenization temperatures, salinity, and fluid trapping pressure).

3.1. Cenozoic Deposits

Characteristics of mineral-forming fluids are presented in Table 2 and shown in Figures 1–5. The information includes 308 temperature and fluid salinity estimates and 106 pressure estimates. Some of these deposits were produced from homogeneously trapped aqueous-carbonic and generally low-salinity fluids that show no discernible evidence of unmixing (Zhemulang, Mazhala, and Bangbu, China; Muteh, Iran; and Zopkhito, Georgia Republic). However, most of these deposits were formed by heterogeneously trapped fluids, with one end-member being an aqueous-saline solution and the other being a high-density gas mixture dominated by CO₂. The trapping temperatures for the fluids range from 128 to 424 °C (median 242 °C) and salinities range from 0.0 to 19.6 wt.% NaCl equiv. (median 3.6 wt.% NaCl equiv.) (Table 8). The fluid trapping pressures vary from 150 to 3600 bar (median 1305 bar). The aqueous-only fluid (not related to fluid unmixing) without traces of fluid heterogenization showed lower homogenization temperatures (146–390 °C) and slightly higher salinities (0.5–19.6 wt.% NaCl equiv) than those of the aqueous phase of the heterogeneous fluids (temperature of 128–124 °C, salinity 0.0–14.6 wt.% NaCl equiv).

3.2. Mesozoic Deposits

Data for mineral-forming fluids are summarized in Table 3 and portrayed in Figures 1–5. The information of the deposits comprises 1478 temperature and fluid salinity estimates and 440 pressure estimates. Some of these deposits were formed by homogeneously aqueous-carbonic fluid without evidence of unmixing. These include Big Hurrah, Willow Creek, Fairbanks, Table Mountain, and Donlin Creek, Alaska, USA; Yata, Dongping, Hanshan, Baidi, Banqi, Dongbeizhai, Gaolong, Gedang, Jinya, Lannigou, Mingshan, Shijia, Wangu, Kuzhubao, Bashishan, Anjiayingzi, Denggezhuang, Rushan, Baijintazi, Heijintaizi, Linglong, Shuiyindong, Guodawa, Songweizi, Tonggoucheng, Xiaomiaoshan, Bojitian, Lannigou, Taipingdong, Zimudang, Qianhe, Erdaogou, Xiaobeigou, Taishang, Jinchangyu,

Gezhen, Hamashi, Pingshui, and Tonggu, China; Daeil and Samgwang, Korea; Lover Dominion and Portland Creek, Canada; Kyuchus, Svetloye, Tas-Uryakhskeye, and Kimpichenskeye, Russia; Gatsuurt, Mongolia; and Canan area, Honduras. The majority of deposits, however, trapped heterogeneous fluids below the appropriate solvi, with unmixing of H₂O- and CO₂-dominant fluid endmembers. Ore-forming fluids had temperatures of 80–515 °C (median 260 °C), salinities of 0.0 to 37.5 wt.% NaCl equiv. (median 5.9 wt.% NaCl equiv.), and pressures of 100 to 4000 bar (median 1200 bar) (Table 8). Just like the previous case, the pure aqueous fluids without traces of fluid heterogenization showed lower homogenization temperatures (80–421 °C) and slightly lower salinities (0.02–32.7 wt.% NaCl equiv) than those of the aqueous phase of the heterogeneous fluids (temperature of 92–515 °C, salinity 0.0–37.5 wt.% NaCl equiv).

Table 2. Parameters of mineralizing fluids of Cenozoic gold deposits.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	<i>T</i> , °C	Salinity *, wt. %	<i>d</i> , g/cm ³	<i>P</i> , bar	Composition **	
Valdez Group, USA	210–280 (2)	0–6.0	-	1000–1500 (2)	CO ₂ + H ₂ O	[6]
Venus, Canada	231–316 (45)	1.8–5.4	-	250–2700 (37)	CO ₂ + H ₂ O	[7]
Monte Rosa gold district, Italy	180–330 (19)	1.0–10.1	0.86–0.93	1000–1500 (2)	CO ₂ + H ₂ O	[8]
Fairview, Oro Fino, Canada	275–313 (2)	2.7–4.7	0.73–0.78	800–1550 (7)	CO ₂ + H ₂ O	[9]
Twin Lakes Canada	270–323 (2)	1.2–8.6	0.77–0.78	-	H ₂ O	[9]
Alaska-Juneau, USA	150–300 (2)	0.0–5.0	-	1000–2000 (2)	CO ₂ + H ₂ O	[10]
Ibex, USA	150–300 (2)	0.0–5.0	-	1000–2000 (2)	CO ₂ + H ₂ O	[10]
Reagan, USA	150–280 (2)	0.0–5.0	-	1000–2000 (2)	CO ₂ + H ₂ O	[10]
Treadwell, USA	190–240 (2)	5.0–8.0	-	800–1500 (2)	H ₂ O	[10]
Bralorne-Pioneer, Canada	140–350 (10)	0.8–5.0	-	500–1750 (4)	CO ₂ + H ₂ O	[11]
Monte Rosa gold district, Italy	230–300 (2)	1.2–1.9	-	600–1300 (2)	CO ₂ + H ₂ O	[12]
Bralorne-Pioneer, Canada	150–390 (36)	0.9–10.5	0.62–0.93	-	H ₂ O	[13]
Callery, New Zealand	300–350 (2)	2.0	-	900–1200 (2)	CO ₂ + H ₂ O	[14]
Shotover, New Zealand	160–200 (2)	0.5	-	500–1000 (2)	CO ₂ + H ₂ O	[14]
Mt. Alta, New Zealand	160–260 (2)	2.0	-	500–1000 (2)	CO ₂ + H ₂ O	[14]
Nenthorn, New Zealand	190 (1)	2.0	-	150 (1)	CO ₂ + H ₂ O	[14]
Böckstein, Austria	240–270 (8)	5	-	700 (1)	CO ₂ + H ₂ O	[15]
Monte Rosa gold district, Italy	250–300 (4)	5	-	1000 (1)	CO ₂ + H ₂ O	[15]
Kensington, USA	170–220 (2)	5.0–8.0	-	900 (2)	CO ₂ + H ₂ O	[16]
Jualin, USA	170–220 (2)	6.5–9.0	-	900 (2)	CO ₂ + H ₂ O	[16]
Shannan area, China	232–335 (4)	4.0–15.0	0.68–0.95	-	H ₂ O	[17]
Muteh, Iran	156–305 (4)	2.2–17.5	-	-	CO ₂ + H ₂ O	[18]
Zopkhito, Georgia Republic	185–380 (53)	0.5–4.9	0.52–0.91	-	H ₂ O	[19]
La Herradura, Mexico	265–283 (7)	3.5–4.1	-	670–2015 (7)	CO ₂ + H ₂ O	[20]
Daping, China	279–424 (8)	3.7–14.6	0.69–0.78	1335–3400 (2)	CO ₂ + H ₂ O	[21]
Mayum, China	229–357 (19)	1.2–5.8	0.65–0.84	1400–3500 (18)	CO ₂ + H ₂ O	[22]
Zhemulang, China	146–292 (24)	3.2–7.7	0.79–0.96	-	H ₂ O	[23]
Mazhala, China	148–303 (30)	1.6–5.1	0.75–0.94	-	H ₂ O	[23]
Qolqoleh, Iran	204–386 (6)	4.9–19.6	-	1600–2000 (2)	CO ₂ + H ₂ O	[24]
Bangbu, China	167–336 (6)	2.2–9.5	0.63–0.96	-	H ₂ O	[25]

Notes: * salinity of fluid expressed in wt% NaCl equiv.; ** composition of gas phase of fluid inclusions; Number of determinations is shown in parentheses.

Table 3. Parameters of mineralizing fluids of Mesozoic gold deposits.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	<i>T</i> , °C	Salinity *, wt. %	<i>d</i> , g/cm ³	<i>P</i> , bar	Composition **	
Oriental mine, USA	280–340 (2)	0.0–3.5	–	670–2500	CO ₂ + H ₂ O	[26]
Big Hurrah mine, USA	155–240 (9)	2.2–6.8	0.88–0.95	-	H ₂ O	[27]
Mouthier Lode, USA	290–350 (2)	2.0	-	1000–2000	CO ₂ + H ₂ O	[28]
Yata, China	150–240 (2)	5.0	0.86–0.96	-	H ₂ O	[29]
Daeil, Korea	243–375 (4)	3.1–9.1	0.56–0.89	-	H ₂ O	[30]
Macraes, New Zealand	300–350 (2)	1.0	-	2500–3500	CO ₂ + H ₂ O	[14]
Glenorchy, New Zealand	200–300 (2)	1.0	-	2000	CO ₂ + H ₂ O	[14]
Barewood, New Zealand	300	1.0–2.0	-	2000	CO ₂ + H ₂ O	[14]
Bendigo, New Zealand	<290	1.9	-	>1000	CO ₂ + H ₂ O	[14]
Bonanza, New Zealand	200	1.5	-	800–1400	CO ₂ + H ₂ O	[14]
Quartz Hill, USA	375 (1)	6.0	-	1350	CO ₂ + H ₂ O	[31]
Lover Dominion, Canada	296 (1)	3.4	-	-	H ₂ O	[32]
Aime, Canada	263 (1)	4.9	-	2300 (1)	CO ₂ + H ₂ O	[32]
Gold Run, Canada	278–293 (2)	4.0–4.3	-	1325–1500 (2)	CO ₂ + H ₂ O	[32]
Portland Creek, Canada	255 (1)	4.0	-	-	H ₂ O	[32]
Lloid, Canada	304–308 (2)	3.8–4.3	-	870–1440 (2)	CO ₂ + H ₂ O	[32]
Hunker Dome, Canada	310–332 (2)	4.0–5.0	-	750–1250 (2)	CO ₂ + H ₂ O	[32]
Mitchell, Canada	296–341 (4)	2.4–6.1	-	450–875 (4)	CO ₂ + H ₂ O	[32]
Sheba, Canada	281–341 (6)	2.9–6.8	-	450–1800 (6)	CO ₂ + H ₂ O	[32]
Lone Star, Canada	292 (1)	3.2	-	300	CO ₂ + H ₂ O	[32]
Hilchey, Canada	297 (1)	5.8	-	300	CO ₂ + H ₂ O	[32]
27 Pup, Canada	313 (1)	3.5	-	300	CO ₂ + H ₂ O	[32]
Violet, Canada	225 (1)	6.1	-	350	CO ₂ + H ₂ O	[32]
Virgin, Canada	198 (1)	5.5	-	625	CO ₂ + H ₂ O	[32]
Amethyst, Canada	341 (1)	1.2	-	350	CO ₂ + H ₂ O	[32]
Samdong, Korea	102–426 (24)	2.7–14.0	0.88–0.94	1300–1900 (2)	CO ₂ + H ₂ O	[33]
Barneys Canyon, USA	225–345 (2)	1.5	0.60–0.85	-	H ₂ O	[34]
Mouse Pass, USA	210–360	1.0–3.0	-	1000–1500	CO ₂ + H ₂ O	[35]
Nuka Bay, USA	250–300	3.0–6.0	-	2300–3000	CO ₂ + H ₂ O	[35]
Chichagof mine, USA	225–250	6.0	-	1000	CO ₂ + H ₂ O	[35]
Berners Bay, USA	200–235	3.0–6.0	-	900	CO ₂ + H ₂ O	[35]
Alaska-Juneau mine, USA	300–375	0.0–5.0	-	1500–4000	CO ₂ + H ₂ O	[35]
Treadwell mine, USA	190–240	0.0–5.0	-	800–1500	CO ₂ + H ₂ O	[35]

Table 3. Cont.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	<i>T</i> , °C	Salinity *, wt. %	<i>d</i> , g/cm ³	<i>P</i> , bar	Composition **	
Sumdum Chief mine, USA	240–320	0.0–5.0	-	800–1500	CO ₂ + H ₂ O	[35]
Willow Creek, USA	300–325	1.0–2.5	-	-	H ₂ O	[35]
Valdez Creek, USA	290–305	-	-	1000–2300	CO ₂ + H ₂ O	[35]
Fairbanks, USA	275–375	3.0–5.0	-	-	H ₂ O	[35]
Ryan Lode, USA	270–350	0.0–8.0	-	500–750	CO ₂ + H ₂ O	[35]
Fort Knox, USA	270–330	0.0–8.0	-	1250–1500	CO ₂ + H ₂ O	[35]
Table Mountain, USA	320–370	3.0–7.0	-	-	H ₂ O	[35]
Rock Creek, USA	184–272	5.0	-	1000–1400	CO ₂ + H ₂ O	[35]
Chandalar, USA	265–300	0.8–3.0	-	750–825	CO ₂ + H ₂ O	[35]
Dongping, China	195–340 (4)	2.5–21.0	0.64–1.04	-	H ₂ O	[36]
Niuxinshan, China	180–336 (11)	4.1–9.6	0.77–0.92	750–3700 (9)	CO ₂ + H ₂ O	[37]
Hanshan, China	150–310 (5)	3.1–10.7	0.72–0.95	-	H ₂ O	[38]
Kyuchus, Russia	118 (1)	2.8	0.97	-	H ₂ O	[39]
Svetloye, Russia	145–215 (4)	6.4–14.0	0.90–1.02	-	H ₂ O	[39]
Tas-Uryakhskoye, Russia	155 (1)	2.0	0.93	-	H ₂ O	[39]
Baidi, China	172–266 (5)	3.9–6.6	0.84–0.93	-	H ₂ O	[40]
Banqi, China	180–230 (2)	3.2	0.86–0.91	-	H ₂ O	[40]
Dongbeizhai, China	120–170 (2)	5.0	0.94–0.98	-	H ₂ O	[40]
Gaolong, China	125–290 (5)	2.4–5.1	0.78–0.96	-	H ₂ O	[40]
Gedang, China	155–305 (4)	3.4–6.0	0.77–0.94	-	H ₂ O	[40]
Jinya, China	143–270 (4)	2.9–5.1	0.82–0.95	-	H ₂ O	[40]
Lannigou, China	160–253 (3)	4.5–4.9	0.84–0.95	-	H ₂ O	[40]
Mingshan, China	136–185 (2)	4.0–5.0	0.92–0.96	-	H ₂ O	[40]
Shijia, China	152–225 (3)	1.9–6.7	0.87–0.93	-	H ₂ O	[40]
Humboldt, USA	170–340 (12)	0.2–11.2	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Dun Glen, USA	150–260 (4)	1.0–8.8	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Santa Rose, USA	200–360 (12)	0.2–8.3	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Ten Mile, USA	240–350 (2)	1.0–7.9	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Eugene, USA	170–330 (12)	0.2–9.5	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Slumbering, USA	180–330 (8)	0.4–10.4	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Antelope, USA	180–340 (8)	0.2–8.4	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Trinity, USA	195–300 (4)	1.0–9.9	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Pine Forest, USA	220–330 (8)	0.4–16.7	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Pueblo, USA	250–350 (4)	0.8–17.5	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]

Table 3. Cont.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	<i>T</i> , °C	Salinity *, wt. %	<i>d</i> , g/cm ³	<i>P</i> , bar	Composition **	
Jackson, USA	100–230 (2)	6.7–15.3	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Quinn River, USA	170–330 (4)	1.8–20.0	-	1200–2400 (2)	CO ₂ + H ₂ O	[41]
Wangu, China	138–310 (14)	3.0–6.0	0.73–0.97	-	H ₂ O	[42]
Kuzhubao and Bashishan, China	180–330 (8)	0.8–13.0	0.77–0.90	-	H ₂ O	[43]
Sanshandao, China	150–355 (35)	1.5–7.1	0.62–0.95	1200–2100 (46)	CO ₂ + H ₂ O	[44]
Dongping, China	250–372 (33)	4.7–8.9	0.64–0.87	600–1800 (31)	CO ₂ + H ₂ O	[45]
Donlin Creek, USA	232–237 (2)	6.3	0.88	-	H ₂ O	[46]
Mayskoye, Russia	119–515 (28)	0.9–37.5	0.57–1.13	420–1240 (28)	CO ₂ + H ₂ O	[47]
Anjiayingzi, China	160–338 (3)	2.0–4.5	-	-	CO ₂ + H ₂ O	[48]
Paishanlou, China	128–447 (14)	3.1–33.3	0.89–0.96	1400–1900 (2)	CO ₂ + H ₂ O	[49]
Denggezhuang, China	80–388 (45)	1.1–16.4	0.71–0.99	-	H ₂ O	[50]
Gubong, Korea	201–432	0.4–17.3	-	670–2100	CO ₂ + CH ₄ + H ₂ O	[51]
Rushan, China	96–324 (4)	0.2–12.6	0.80–1.04	-	CO ₂ + H ₂ O	[52]
Baijintazi, China	180–386 (10)	6.9–13.2	0.72–0.97	-	H ₂ O	[53]
Heijintaizi, China	182–361 (15)	6.7–18.5	0.85–0.94	-	H ₂ O	[53]
Nezhdaninskoye, Russia	129–378 (40)	0.8–31.1	0.65–1.12	390–1840 (33)	CO ₂ + H ₂ O	[54]
Linglong, China	80–360 (14)	3.0–14.6	0.60–1.00	-	H ₂ O	[55]
Sarylakh, Russia	130–380 (3)	0.5–6.4	0.62–0.94	-	H ₂ O	[56]
Sentachan, Russia	200–325 (2)	5.7	0.73–0.91	-	H ₂ O	[56]
Dyby, Russia	226–495 (6)	6.9–35.3	0.86–0.91	477–1495 (4)	CO ₂ + H ₂ O	[57]
Ergelyakh 1, Russia	243–358 (5)	3.7–32.7	0.84–0.98	-	H ₂ O	[57]
Ergelyakh 2, Russia	264–304 (4)	4.5–8.6	0.77–0.82	940–1140 (2)	CO ₂ + H ₂ O	[57]
Ergelyakh 3, Russia	268 (1)	3.6	0.80	-	H ₂ O	[57]
Arkachan, Russia	250–385 (2)	3.7–26.3	0.83–0.89	1300–1700 (2)	CO ₂ + H ₂ O	[57]
Kimpichenskoye Russia	200 (1)	32.0	1.13	-	H ₂ O	[58]
Arkachan, Russia	230–290 (4)	12.0–20.0	0.87–0.99	-	H ₂ O	[58]
Natalkinskoye, Russia	205–359 (12)	1.9–6.2	0.60–0.91	1120–2260 (13)	CO ₂ + H ₂ O	[59]
Rodionovskoye, Russia	294–337 (2)	6.8–7.3	0.87–0.95	1180–1530 (2)	CO ₂ + H ₂ O	[60]
Shuiyindong, China	212–225 (2)	4.7–6.3	0.89	-	H ₂ O	[61]
Yata, China	151–261 (9)	2.1–7.2	0.85–0.94	-	H ₂ O	[61]
Samgwang, Korea	145–385 (13)	0.1–11.2	0.70–0.93	-	H ₂ O	[62]
Sentachan, Russia	155–320 (11)	1.6–7.4	0.82–1.03	1310–1960 (13)	CO ₂ + H ₂ O	[63]
Sarylakh, Russia	170–312 (12)	1.6–6.8	0.89–1.06	300–3430 (17)	CO ₂ + H ₂ O	[63]

Table 3. Cont.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	<i>T</i> , °C	Salinity *, wt. %	<i>d</i> , g/cm ³	<i>P</i> , bar	Composition **	
Guodawa, Songweizi, Tonggoucheng, and Xiaomiaoshan, China	115–335 (20)	5.6–11.6	0.72–1.02	-	H ₂ O	[64]
Shkolnoye, Russia	189–350 (23)	2.1–9.3	0.77–1.03	365–2320 (8)	CO ₂ + H ₂ O	[65]
Badran, Russia	140–320 (3)	4.5–10	0.80–0.96	100–2000 (2)	CO ₂ + H ₂ O	[66]
Pogromnoye, Russia	283–363 (6)	6.5–11.1	0.81–1.02	980–2800 (11)	CO ₂ + H ₂ O	[67]
Wenyu, China	114–330 (12)	0.1–12.8	0.63–0.98	850–1780 (4)	CO ₂ + H ₂ O	[68]
Banqi, China	210–290 (2)	2.3–4.2	0.77–0.87	-	H ₂ O	[69]
Bojitian, China	117–193 (3)	0.5–6.9	0.93–0.95	-	H ₂ O	[69]
Lannigou, China	85–272 (8)	0.5–8.7	0.85–0.97	-	H ₂ O	[69]
Shuiyindong, China	126–225 (5)	0.2–6.3	0.89–0.95	-	H ₂ O	[69]
Taipingdong, China	172–269 (7)	1.9–7.3	0.84–0.94	-	H ₂ O	[69]
Yata, China	106–231 (3)	0.7–7.9	0.90–0.96	-	H ₂ O	[69]
Zimudang, China	95–273 (5)	0.2–7.5	0.84–0.97	-	H ₂ O	[69]
Yangzhaiyu, China	175–313 (16)	5.1–13.6	0.78–0.99	-	CO ₂ + H ₂ O	[70]
Qianhe, China	160–305 (64)	6.1–21.8	0.93–0.95	-	H ₂ O	[71]
Sanshandao, China	112–350 (12)	0.4–10.3	0.75–0.96	-	H ₂ O	[72]
Jinshan China	109–340 (15)	0.6–8.9	0.70–0.96	-	H ₂ O	[73]
Gatsuurt, Mongolia	194–355 (10)	-	-	-	CO ₂ + H ₂ O	[74]
Taipingdong, China	97–300 (8)	0.02–8.1	-	-	CO ₂ + H ₂ O	[75]
Zimudang, China	99–300 (6)	0.04–7.5	-	-	CO ₂ + H ₂ O	[75]
Shuiyindong, China	83–250 (8)	0.02–6.9	-	-	CO ₂ + H ₂ O	[75]
Bojitian, China	80–198 (2)	0.9–7.5	-	-	H ₂ O	[75]
Wenyu, China	114–417 (36)	0.0–12.8	-	1570–2760 (6)	CO ₂ + H ₂ O	[76]
Sanshandao, China	101–390 (6)	0.2–18.4	0.75–0.78	-	H ₂ O	[77]
Arkachan, Russia	200–385 (19)	3.7–26.3	0.84–1.07	1060–1830 (13)	CO ₂ + H ₂ O	[78]
Canan area, Honduras	240–338 (8)	0.9–6.2	0.68–0.83	-	H ₂ O	[79]
Zhaishang, China	92–372 (20)	0.2–23.1	0.71–1.03	238–781 (20)	H ₂ O	[80]
Qiangma, China	145–365 (18)	0.0–12.7	-	1750–2810 (4)	CO ₂ + H ₂ O	[81]
Dongfeng, China	117–341 (6)	0.5–11.7	0.57–1.00	2260–3380 (2)	CO ₂ + H ₂ O	[82]
Linglong, China	103–374 (8)	0.3–13.3	0.82–1.01	2280–3360 (2)	CO ₂ + H ₂ O	[82]
Erdaogou, Xiaobeigou, China	125–370 (46)	0.9–17.4	0.81–0.98	-	H ₂ O	[83]
Sanshandao, China	101–390 (3)	0.2–18.4	0.75–0.78	-	H ₂ O	[84]
Anjiayingzi, China	180–358 (11)	1.3–15.6	0.82–0.91	500–1100	CO ₂ + H ₂ O	[85]

Table 3. Cont.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	<i>T</i> , °C	Salinity *, wt. %	<i>d</i> , g/cm ³	<i>P</i> , bar	Composition **	
Nancha, China	132–432 (12)	0.4–11.7	0.51–0.94	1520–3670 (3)	CO ₂ + H ₂ O	[86]
Taishang, China	158–336 (39)	0.2–9.1	0.73–0.92	-	H ₂ O	[87]
Jinchangyu, China	120–410 (10)	3.0–28.3	-	-	CO ₂ + H ₂ O	[88]
Hetai, China	130–310 (4)	2.7–13.9	0.70–1.02	500–1710 (4)	CO ₂ + H ₂ O	[89]
Liyuan, China	136–408 (18)	0.5–12.6	0.65–0.98	1310–3470 (4)	CO ₂ + H ₂ O	[90]
Baolun, China	140–376 (6)	3.0–9.0	-	1000–1600 (2)	CO ₂ + H ₂ O	[91]
Gezhen, China	140–370 (8)	0.5–10.5	-	-	H ₂ O	[91]
Dongping, China	154–382 (68)	0.1–35.4	-	1000 (1)	CO ₂ + H ₂ O	[92]
Xiadian, China	111–418 (16)	0.2–22.9	0.61–1.11	400–2470 (4)	CO ₂ + H ₂ O	[93]
Luoshan, China	212–393 (12)	3.0–9.1	0.47–0.92	770–1850 (2)	CO ₂ + H ₂ O	[94]
Fushan, China	211–380 (18)	0.0–11.2	0.43–0.98	770–1850 (2)	CO ₂ + H ₂ O	[94]
Bake, China	157–402 (12)	2.2–13.7	-	460–800 (5)	CO ₂ + H ₂ O	[95]
Chanziping, China	138–156 (18)	1.8–11.9	-	400–960 (12)	CO ₂ + H ₂ O	[95]
Dagaowu, China	176 (2)	4.9–9.6	-	460 (1)	CO ₂ + H ₂ O	[95]
Fenshuiao, China	178–183 (2)	10.1–10.2	-	220–680 (2)	CO ₂ + H ₂ O	[95]
Gaokeng, China	171 (2)	6.5–10.5	-	450 (1)	CO ₂ + H ₂ O	[95]
Hamashi, China	145–421 (3)	2.9–13.1	-	-	H ₂ O	[95]
Huangjindong, China	225–397 (9)	3.6–10.9	-	990 (2)	CO ₂ + H ₂ O	[95]
Huangshan, China	156–350 (3)	1.2–24.0	-	420–590 (2)	CO ₂ + H ₂ O	[95]
Huangtudian, China	190–260 (2)	6.6–6.9	-	390–480 (2)	CO ₂ + H ₂ O	[95]
Jinshan, China	109–372 (53)	0.6–16.5	-	350–950 (10)	CO ₂ + H ₂ O	[95]
Kengtou, China	148–160 (2)	6.4–9.1	-	390 (1)	CO ₂ + H ₂ O	[95]
Miaoxiafan, China	158 (2)	4.1–9.2	-	410 (1)	CO ₂ + H ₂ O	[95]
Mobin, China	170–203 (9)	9.3–2.1	-	210–790 (4)	CO ₂ + H ₂ O	[95]
Pingshui, China	214–282 (6)	1.2–8.7	-	-	H ₂ O	[95]
Taojinchong, China	107–352 (37)	0.5–20.1	-	580–770 (2)	CO ₂ + H ₂ O	[95]
Tonggu, China	97–300 (11)	1.1–10.4	-	-	H ₂ O	[95]
Tongshulin, China	183 920	3.9–9.9	-	480 910	CO ₂ + H ₂ O	[95]
Wangu, China	138–310 (26)	0.8–12.6	-	-	H ₂ O	[95]
Xi'an, China	147–325 (8)	3.3–8.5	-	660 (1)	CO ₂ + H ₂ O	[95]
Xichong, China	200–304 (5)	6.1–7.5	-	480 (2)	CO ₂ + H ₂ O	[95]
Xintang, China	125 (2)	2.9–4.2	-	320 (1)	CO ₂ + H ₂ O	[95]
Yanghanwu, China	151–185 (4)	3.4–8.2	-	400–480 (2)	CO ₂ + H ₂ O	[95]

Notes: * salinity of fluid expressed in wt% NaCl equiv.; ** composition of gas phase of fluid inclusions; Number of determinations is shown in parentheses.

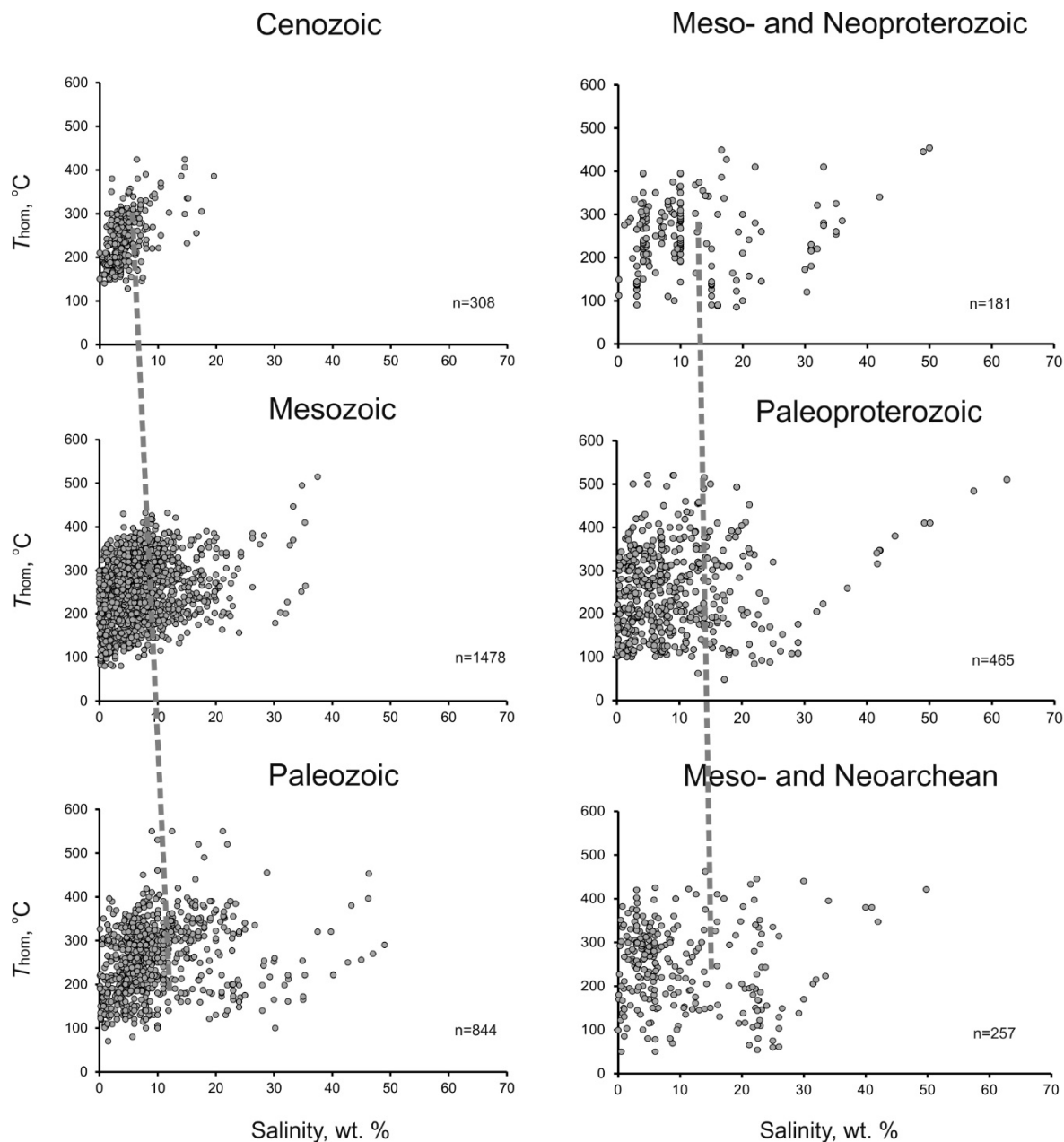


Figure 1. Temperature–salt concentration diagrams for mineralizing fluids at gold deposits of different age. Here and in Figures 2–5, n is the number of measurements. Here and on Figure 2 trendlines are shown as dashed lines. The initial data on the fluid parameters are provided as Supplementary Materials.

3.3. Paleozoic Deposits

Parameters of fluids that produced orogenic gold deposits are summarized in Table 4 and Figures 1–5 (844 temperature and fluid salinity estimates and 375 pressure estimates). Some of the deposits were formed in the one-phase fluid field above the appropriate solvi, including Hill End goldfield, Flying Pig, Tyrconnel, Charters Towers, Stawell-Magdala, Maldon, Mount Piper, Woods Point, and Walhalla, Australia; Haut Allier, Biards district, and Moulin de Cheni, France; Pataz region, Peru; Vorontsovskoye, Russia; and Jiapigou, Bulong, Qingshui, and Woxi, China. Most of them, however, formed from heterogeneous fluids, with H_2O - and CO_2 -dominant fluid endmembers. The fluids forming the gold deposits had temperatures of 70 to 550 °C (median 267 °C), salinities of 0.1 to 49.0 wt.% NaCl equiv. (median 7.3 wt.% NaCl equiv.), and fluid pressure of 80–5030 bar (median 1500 bar) (Table 8). The comparison of homogeneous aqueous fluids with the aqueous phase

of the heterogeneous fluids revealed the slightly narrower range of homogenization temperatures (92–455 °C) and salinities (0.2–46.2 wt.% NaCl equiv) of the first ones.

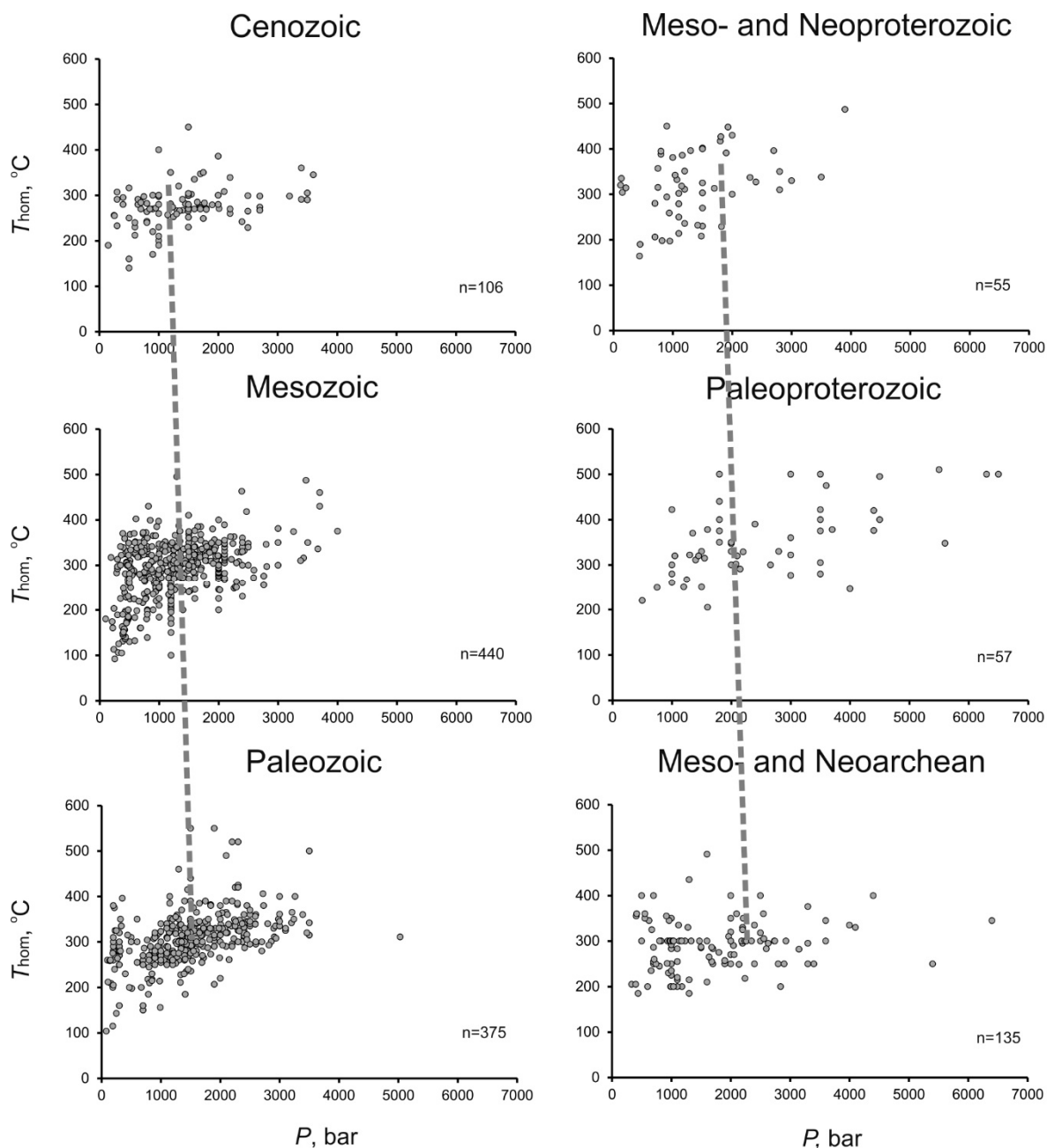


Figure 2. Temperature–pressure diagrams for mineralizing fluids at gold deposits of different age.

3.4. Meso- and Neoproterozoic Deposits

Table 5 and Figures 1–5 show characteristics of the mineral-forming fluids of orogenic gold deposits. The information of the deposits comprises 181 temperature and fluid salinity estimates and 55 pressure estimates. A few of these deposits were formed in the one-phase fluid field above the appropriate solvi (e.g., Paiol mine, Brazil; and Udereyskoye, Russia). Most of the deposits were formed from fluids trapped in the two-phase field, with H_2O - and CO_2 - or N_2 -dominant fluid endmembers. Ore-forming fluids for the gold deposits had ranges of temperature of 85–454 °C (median 255 °C), salinity of 0.1–50.0 wt.% NaCl equiv. (median 10.0 wt.% NaCl equiv.), and fluid pressure of 120–3900 bar (median 1200 bar) (Table 8). Again, as in the previous case, homogenization

temperatures (90–410 °C) and salinities (3.0–33.0 wt.% NaCl equiv) are varied in the narrower ranges than the parameters of the aqueous phase of the heterogeneous fluids (temperature of 85–454 °C, salinity 0.1–50.0 wt.% NaCl equiv).

3.5. Paleoproterozoic Deposits

Table 6 and Figures 1–5 show characteristics of the mineral-forming fluids of orogenic gold deposits. The information of the deposits comprises 465 temperature and fluid salinity estimates and 57 pressure estimates. These deposits typically contain fluid inclusions of two types: aqueous fluid of different salinity and homogeneous fluid of high-density gases. The gas inclusions are dominated by either CO₂ or N₂. Inclusions of the two types not always occur in association with one another, and hence, pressure was evaluated not for all of the deposits. Ore-forming fluids for the gold deposits had ranges of temperature of 48–520 °C (median 252 °C), salinity of 0.5–62.4 wt.% NaCl equiv. (median 7.1 wt.% NaCl equiv.), and fluid pressure of 500–6500 bar (median 2080 bar) (Table 8).

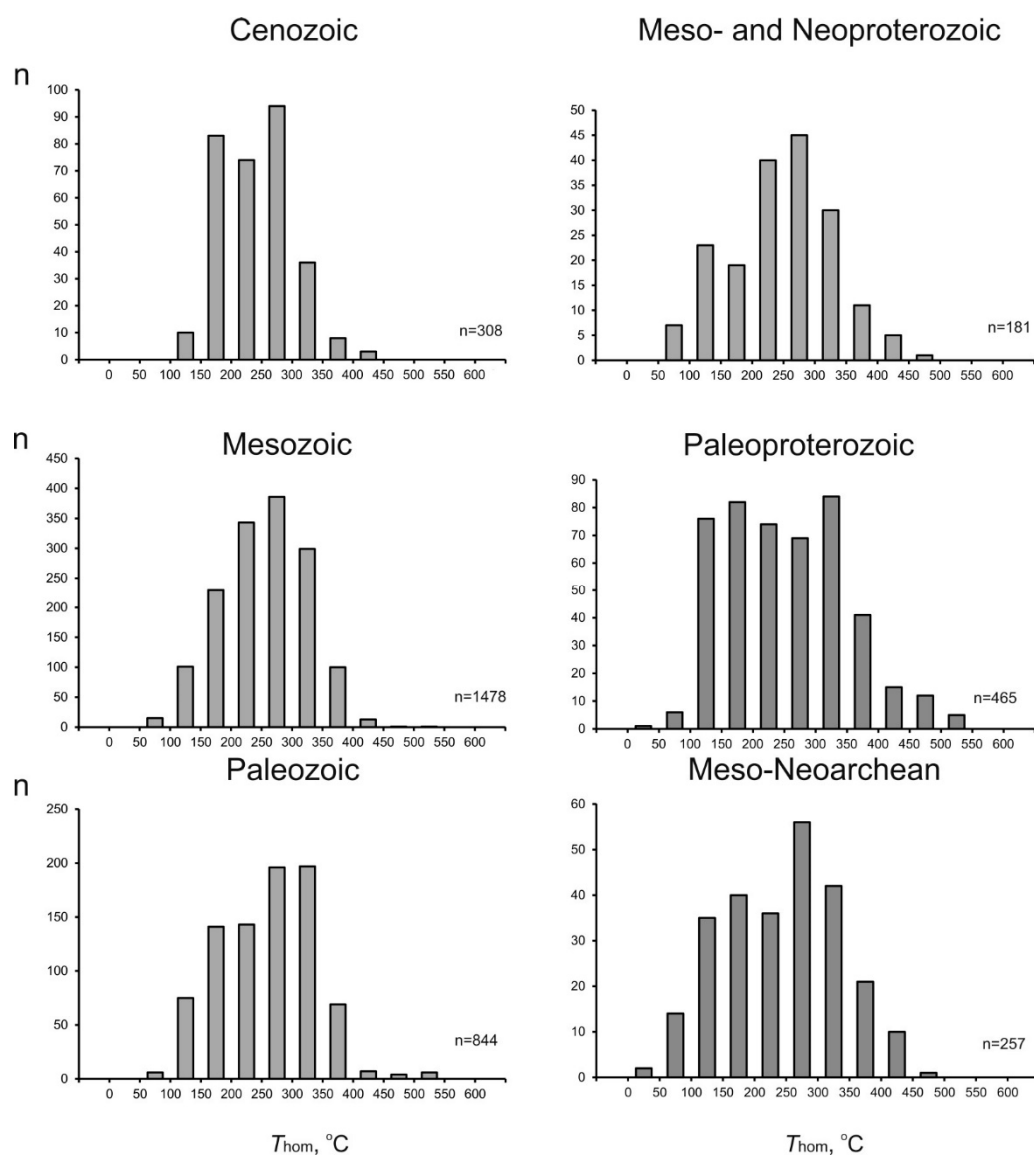


Figure 3. Histograms of the temperatures of mineralizing fluids at gold deposits of different age.

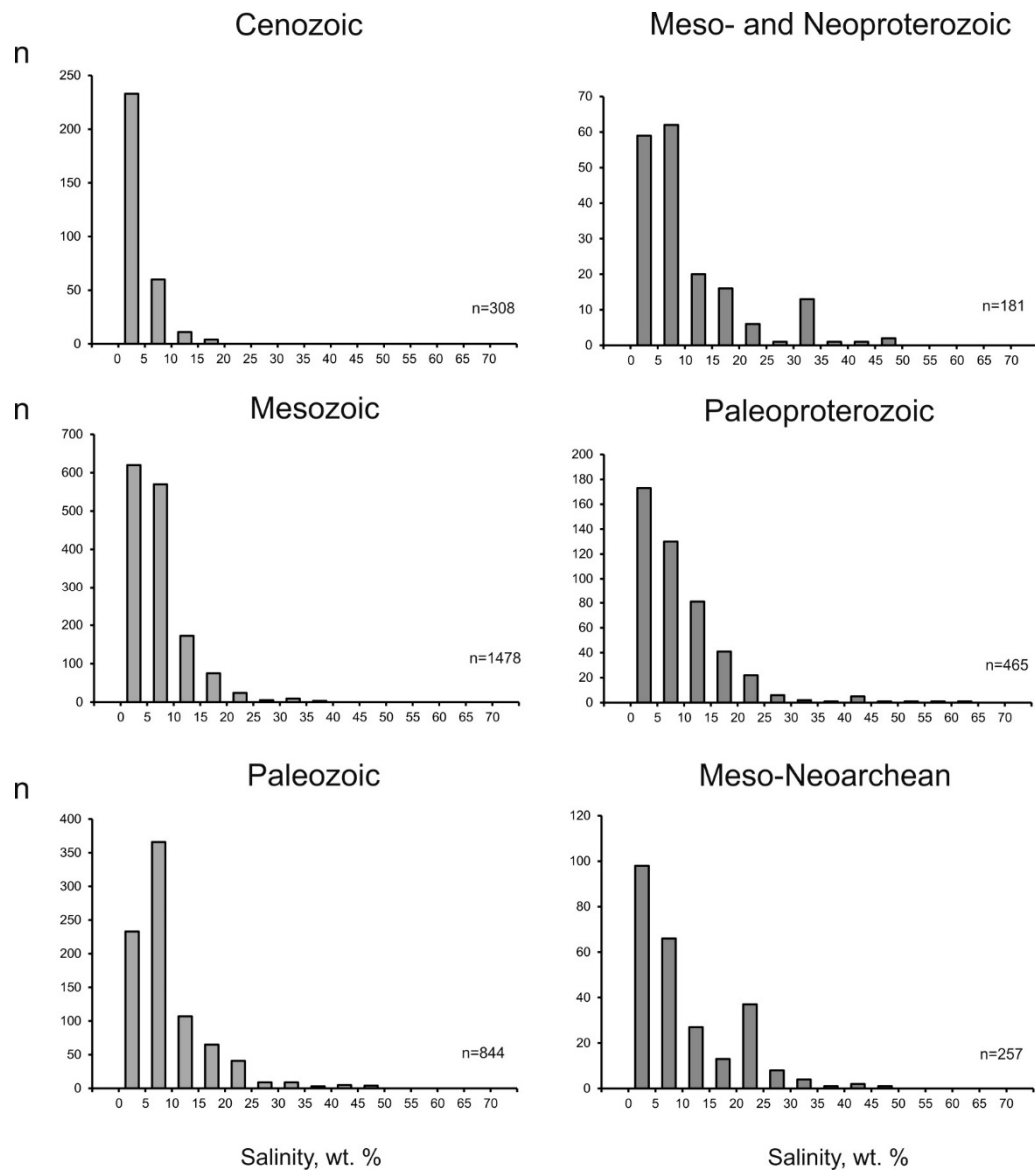


Figure 4. Histograms of the salinity of mineralizing fluids at gold deposits of different age.

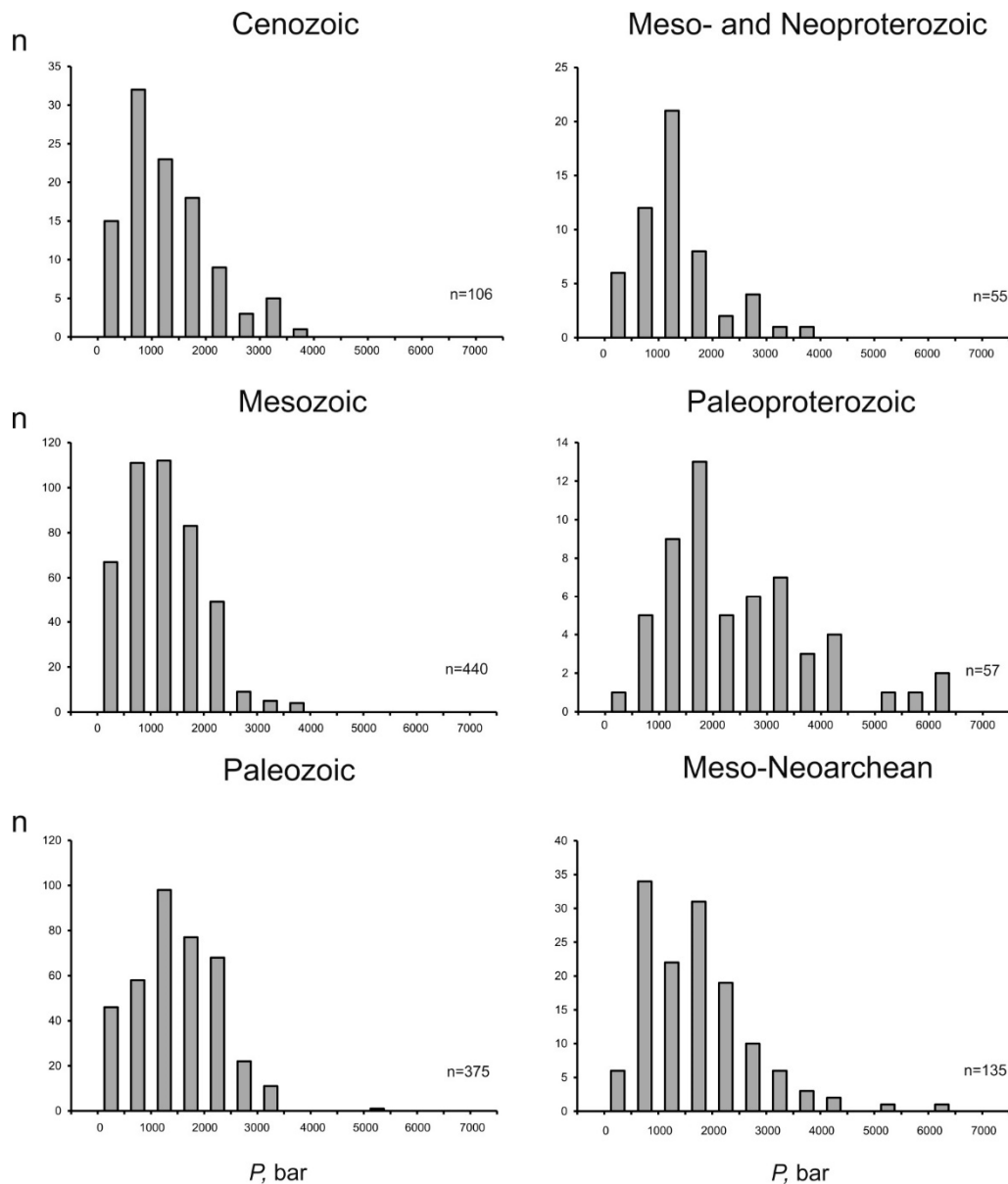


Figure 5. Histograms of the pressure of mineralizing fluids at gold deposits of different age.

3.6. Meso-Neoproterozoic Deposits

Parameters for the fluids from orogenic gold deposits are summarized in Table 7 and Figures 1–5. A few deposits were produced by trapping of a homogeneous aqueous or gaseous fluid (e.g., Kolar and Hutti, India, and Wiluna, Australia), but most deposits formed by trapping of heterogeneous fluids, with H₂O- and CO₂- or CH₄-dominant fluid endmembers. The ore-forming fluids had a temperature range of 50–462 °C (median 254 °C), salinity of 0.0–49.8 wt.% NaCl equiv. (median 6.1 wt.% NaCl equiv.), and fluid pressure of 330 to 6400 bar (median 1680 bar) (Table 8).

It should be noted that, for all time intervals under consideration, the parameters of fluids from which the large gold deposits (>100 tonnes Au) were formed do not differ from the total sample of corresponding time (Table 9).

Table 4. Parameters of mineralizing fluids of Paleozoic gold deposits.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	T, °C	Salinity *, wt. %	d, g/cm ³	P, bar	Composition **	
Hill End goldfield, Australia	260–360 (2)	2.4	0.59–0.80	-	H ₂ O	[96]
Haut Allier, France	260–420 (10)	0.5–8.1	0.44–0.85	-	H ₂ O	[97]
Kvartsytovye gorki, Kazakhstan	255–305 (7)	6.0–7.0	0.93–0.94	275–900 (4)	CO ₂ + CH ₄ + H ₂ O	[98]
Zholymbet, Kazakhstan	255–345 (45)	7.0–17.0	0.89–1.04	1000–2100 (4)	CO ₂ + H ₂ O	[98]
Bestobe, Kazakhstan	270–315 (19)	5.0–14.0	1.03–1.08	900–1600 (8)	CO ₂ + CH ₄ + H ₂ O	[98]
N. Aksu, Kazakhstan	305–365 (20)	12.0–17.0	0.94–1.01	1400–2600 (8)	CO ₂ + CH ₄ + H ₂ O	[98]
Stepnyak, Kazakhstan	270–365 (14)	11–13.0	0.96–1.03	1100–1800 (6)	CO ₂ + H ₂ O	[98]
S. Aksu, Kazakhstan	190–345 (44)	8.0–12.0	0.89–1.05	1200–2800 (8)	CO ₂ + CH ₄ + H ₂ O	[98]
Zhana-Tyube, Kazakhstan	255–355 (43)	9.0–12.0	0.88–1.08	1250–3500 (11)	CO ₂ + CH ₄ + H ₂ S + H ₂ O	[98]
Flying Pig, Australia	135–370 (32)	1.1–10.1	0.56–0.96	-	H ₂ O	[99]
Tyrconnel, Australia	280 (1)	4.7	0.8	-	H ₂ O	[99]
Pataz region, Peru	130–320 (9)	7.0–37.5	0.76–1.06	-	H ₂ O	[100]
Saralinskoye, Russia	150–365 (8)	6.3–29.3	0.77–1.07	770–2900 (12)	CO ₂ + CH ₄ + H ₂ O	[101]
Nagambie, Australia	130–305 (7)	3.7–6.4	0.76–0.96	850–1100 (2)	CO ₂ + H ₂ O	[102]
Kommunar, Russia	210–340 (50)	7.9–15.2	0.89–1.06	930–3500 (11)	CO ₂ + CH ₄ , H ₂ O	[103]
Zarmitan, Uzbekistan	270–380 (16)	3.5–20.0	0.74–1.07	820–2730 (30)	CO ₂ + CH ₄ + H ₂ O	[104]
Deborah, Australia	220–400 (3)	0.1–10.0	0.65–0.93	2000–3000 (2)	CO ₂ + CH ₄ + H ₂ O	[105]
Sukhoi log, Russia	165–380 (45)	3.7–9.5	0.72–1.06	230–2450 (28)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[106]
Berezovskoye, Russia	270–365 (14)	9.5–26.7	0.91–1.09	1470–3460 (21)	CO ₂ + H ₂ O	[107]
Fosterville, Australia	170 (1)	0.5	0.90	-	H ₂ O	[108]
Vorontsovskoye, Russia	100–150 (7)	6.4–9.2	0.98–1.00	-	H ₂ O	[39]
Biards district, France	125–375 (6)	1.7–7.4	0.54–0.97	-	H ₂ O	[109]
Mayskoye, Russia	100–455 (29)	1.4–42.7	0.63–1.28	-	CO ₂ + CH ₄ + H ₂ O	[110]
CSA deposit, Cobar, Australia	200–350 (4)	0.1–5.0	0.66–0.91	1500–2000 (4)	CO ₂ + H ₂ O	[111]
Moulin de Cheni, France	150–250 (2)	4.0–8.0	0.87–0.95	-	H ₂ O	[112]
Jiapigou, China	150–350 (4)	0.7–6.5	0.58–0.93	-	H ₂ O	[113]
Bulong, China	160–395 (30)	5.3–46.2	0.63–1.18	-	H ₂ O	[114]
Charters Tauers, Australia	80–305 (19)	0.2–28.3	0.71–1.08	-	H ₂ O	[115]
Sarekoubu, China	255–395 (5)	-	-	-	CO ₂ + CH ₄ + H ₂ O, H ₂ O	[116]
Qingshui, China	155–355 (3)	3.1–7.5	0.69–0.94	-	H ₂ O	[117]
Tanjianshan, China	120–320 (5)	3.7–10.8	0.80–1.00	-	CO ₂ + CH ₄ + H ₂ O	[118]
Sandwich Point, Canada	150–335 (26)	2.0–25.0	0.69–1.09	-	CO ₂ + CH ₄ + H ₂ O	[119]
Fosterville, Australia	119–264	0.1–10.7	0.88–0.95	1800–2400	CO ₂ + CH ₄ + N ₂ + H ₂ O	[120]
Stawell-Magdala, Australia	110–238	1.4–5.6	0.86–0.97		H ₂ O	[120]
Bendigo, Australia	84–315	0.9–7.8	0.77–0.94	1400–1600	CO ₂ + CH ₄ + N ₂ + H ₂ O	[120]
Wattle Gully, Australia	70–225	1.5–6.3	-	1600	CO ₂ + CH ₄ + N ₂ + H ₂ O	[120]
Maldon (1), Australia	177–187	20.3–21.6	0.85–1.04	-	H ₂ O	[120]
Maldon (2), Australia	101–379	0.9–13.4	0.74–0.97	-	H ₂ O	[120]
Mount Piper, Australia	92–331	0.7–7.1	0.74–0.90	-	H ₂ O	[120]
Woods Point, Australia	129–279	1.6–4.0	0.78–0.95	-	H ₂ O	[120]
Walhalla, Australia	122–283	0.2–6.9	0.85–0.94	-	H ₂ O	[120]
Bogunayskoye, Russia	110–350 (88)	0.2–49.0	0.73–1.22	100–1600 (31)	CO ₂ + CH ₄ + N ₂ + H ₂ S, H ₂ O	[121]
Annage, China	140–380 (42)	0.5–22.0	0.71–1.02	790–1300 (2)	CO ₂ + CH ₄ + H ₂ O	[122]
Woxi, China	178–357 (24)	1.6–9.3	0.71–0.88	-	H ₂ O	[123]
Huangshan, China	127–376 (34)	0.2–9.6	0.65–0.94	870–2610 (34)	CO ₂ + H ₂ O	[124]
Yingchengzi, China	104–400 (12)	1.1–12.4	0.62–0.97	80–3260 (9)	CO ₂ + H ₂ O	[125]
Limarinho, Portugal	180–330 (6)	3.0–7.3	0.73–0.91	600–3500 (6)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[126]
Vasil'kovskoe, Kazakhstan	120–550(90)	2.0–20.0	0.46–0.96	200–2500 (68)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[127]
Woxi, China	109–396 (35)	0.1–12.5	-	140–470 (10)	CO ₂ + H ₂ O	[95]
Sukoi Log, Russia	130–385 (61)	3.7–9.5	0.65–1.09	640–2630 (35)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[128]
Verninskoye, Russia	136–356 (31)	1.4–8.1	0.84–1.05	570–3150 (10)	CO ₂ + H ₂ O	[128]
Dogaldyn, Russia	128–339 (12)	1.4–7.3	0.90–1.05	960–3230 (10)	CO ₂ + H ₂ O	[128]
Uryakh, Russia	191–361 (7)	2.5–9.1	0.94–1.08	1050–3290 (6)	CO ₂ + H ₂ O	[128]
Irokinda, Russia	179–453 (31)	3.9–46.3	0.97–1.15	840–5030 (8)	CO ₂ + H ₂ O	[128]

Notes: * salinity of fluid expressed in wt% NaCl equiv.; ** composition of gas phase of fluid inclusions; Number of determinations is shown in parentheses.

Table 5. Parameters of ore-forming fluids of Meso- and Neoproterozoic gold deposits.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	T, °C	Salinity *, wt. %	d, g/cm ³	P, bar	Composition **	
Olimpiadinskoye, Russia	105–410 (2)	1.9–28.7	0.68–0.93	255–3045 (29)	CO ₂ + CH ₄ + N ₂ + H ₂ S, H ₂ O	[129]
Cachoeira de Minas, Sao Francisco, Brazil	250–350 (2)	6.0	0.68–0.86	2000 (1)	CO ₂	[130]
Veduga, Russia	164–368 (12)	8.2–19.3	0.72–1.04	120–1820 (8)	CO ₂ + CH ₄ , CH ₄ , H ₂ O	[131]
Olimpiadinskoye, Russia	190–449 (10)	4.8–17.4	0.67–0.92	450–2700 (11)	CH ₄ , N ₂ , CO ₂ + N ₂ , H ₂ O	[131]
Harnas area, Sweden	85–395 (84)	3.0–19.0	0.48–1.11	-	CO ₂ , H ₂ O	[132]
Paio mine, Brazil	90–410 (16)	3.0–33.0	0.81–1.07	-	H ₂ O	[133]
Udereyskoye, Russia	120–180 (2)	30.3	1.12–1.20	-	H ₂ O	[56]
Tunkillia, Nuckulla Hill, Barns, and Weednanna, Central Gawler Craton, Australia	88–350 (18)	0.1–23.0	0.68–1.13	-	CO ₂ , H ₂ O	[134]
Taroola gold field, S. Australia	265–335 (9)	1.6–6.7	0.69–0.92	-	CO ₂ + CH ₄ , H ₂ O	[135]
Telfer, Australia	143–454 (135)	2.0–50.0	-	1500–3000 (2)	CO ₂ , H ₂ O	[136]

Notes: * salinity of fluid expressed in wt% NaCl equiv.; ** composition of gas phase of fluid inclusions; Number of determinations is shown in parentheses.

Table 6. Parameters of ore-forming fluids of Paleoproterozoic gold deposits.

Deposit, Region	Physicochemical Parameters of Fluids					Reference
	T, °C	Salinity *, wt. %	d, g/cm ³	P, bar	Composition **	
Tartan Lake, Canada	250–390 (4)	2.2–12.6	0.44–0.91	1200–2400 (2)	CO ₂ , H ₂ O	[137]
Star Lake, Canada	100–520 (112)	0.5–42.1	0.30–1.40	1000–6300 (14)	CO ₂ + CH ₄ , H ₂ O	[138]
Flin Flon Domain, Canada	174–331 (20)	0.4–16.2	0.65–1.01	-	CO ₂ , H ₂ O	[139]
Pirila, Finland	130–325 (4)	1.8–25.0	0.87–1.00	1500–1800 (2)	CO ₂ + CH ₄ , H ₂ O	[140]
Star Lake (La Ronge), Canada	160–340 (5)	1.3–8.2	0.69–0.97	-	CO ₂ , H ₂ O	[141]
Caxias, Brazil	205–378 (2)	10.8	0.70–0.95	1600–3700 (3)	CO ₂ + N ₂ , H ₂ O	[142]
Fazenda Canto, Brazil	280–500 (6)	2.6–4.0	0.72–0.93	1000–3500 (4)	CO ₂ + CH ₄ + N ₂ , H ₂ O	[143]
Fazenda Maria Preta, Brazil	320–420 (2)	-	-	2100–4400 (2)	CO ₂ + CH ₄ + N ₂ , H ₂ O	[143]
Fazenda Brasileiro, Brazil	400–500 (7)	-	-	1800–6500 (7)	CO ₂ + CH ₄ + N ₂ , H ₂ O	[143]
Guarim, Brazil	140–310 (4)	5.6–5.7	0.76–0.97	860–2900 (4)	CO ₂ + CH ₄ + N ₂ , H ₂ O	[144]
Batman, Australia	242–458 (17)	1.8–20.6	0.45–0.96	-	CO ₂ + CH ₄ , CH ₄ , H ₂ O	[145]
Serrinha, Brazil	280–430 (4)	4.5–21.0	0.44–0.93	1300–3000 (2)	CO ₂ + CH ₄ + N ₂ , H ₂ O	[146]
Callie, Australia	48–404 (61)	0.5–33.0	0.52–1.19	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[147]
Coyote Prospect, Australia	183–434 (10)	0.1–12.5	0.55–0.98	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[147]
Groudrust, Australia	161–490 (9)	0.2–13.9	0.49–0.97	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[147]
Tanami gold field, Australia	101–452 (48)	0.1–21.2	0.57–1.10	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[147]
Angovia, W. Africa	156–370 (20)	1.2–8.4	0.69–0.98	1050–1350 (2)	CO ₂ + CH ₄ + N ₂	[148]
Chega Tudo, Brazil	100–371 (42)	0.2–12.3	0.52–1.04	2000–3000 (2)	CO ₂ + CH ₄ , CO ₂ , H ₂ O	[149]
Bjorkdal, Sweden	136–400 (13)	2.2–14.0	0.55–1.01	500–1800 (2)	CO ₂ , H ₂ O	[150]
Carara, Brazil	264–346 (2)	5.0–5.4	0.66–0.82	1800–3600 (2)	CO ₂ + CH ₄ + N ₂	[151]
Morila, W. Africa	175–339 (8)	3.0–20.3	0.65–1.03	-	CH ₄ + N ₂ , H ₂ O	[152]
Baboto, Mali, W Africa	255–320 (3)	1.5–10.7	0.80–0.81	-	CO ₂ + CH ₄ + N ₂ + H ₂ O	[153]
Gara, Mali, W. Africa	140–380 (15)	4.5–57.1	0.78–1.24	750–2200 (4)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[153]
Loulo–3, Mali, W Africa	170–310 (12)	0.2–11.7	0.75–0.93	1550 (1)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[153]
Yalea, Mali, W. Africa	175–519 (15)	0.7–62.4	0.75–1.60	1450 (1)	CO ₂ + CH ₄ + N ₂ + H ₂ O	[153]
Piaba, Brasil	183–377	2.5–7.2	0.96–0.99	1250–2080	CO ₂ + CH ₄ , H ₂ O	[154]
Turmalina, Brazil	106–393 (18)	0.2–23.8	-	1000–2000	CO ₂ , H ₂ O	[155]
Piaba, Brasil	180–360	2.5–7.2	-	1500–2800	CO ₂ , H ₂ O	[156]
Julie, Ghana	210–275 (28)	1.9–8.6	0.41–0.99	-	CO ₂ , H ₂ O	[157]
Lamego, Brazil	300–375 (18)	2.0–9.0	0.68–0.94	2660–3500 (3)	CO ₂ + CH ₄	[158]

Notes: * salinity of fluid expressed in wt% NaCl equiv.; ** composition of gas phase of fluid inclusions; Number of determinations is shown in parentheses.

Table 7. Parameters of mineralizing fluids of Meso-Neoproterozoic gold deposits.

Deposit, Region	Physicochemical parameters of fluids					Reference
	T, °C	Salinity *, wt. %	d, g/cm ³	P, bar	Composition **	
Henderson, Canada	205–215 (2)	31.5–32.0	1.11–1.25	330–1300 (12)	CO ₂ + H ₂ O	[159]
McInture-Hollinger, Canada	175–348 (5)	6.1–19.8	0.79–1.00	-	CO ₂ + CH ₄ + N ₂ + H ₂ O	[160]
Kolar, India	210–420 (14)	3.0–12.0	0.70–0.85	1300–1600 (2)	CO ₂	[161]
Renabie, Canada	161–360 (3)	6.0–12.5	0.89–1.00	2550 (1)	CO ₂ + H ₂ O	[162]
Mink Lake, Canada	250–345 (7)	5.3–6.1	0.65–0.85	-	CO ₂ + H ₂ O	[163]
Sigma, Canada	60–395 (17)	25.0–34.0	0.65–1.07	2000 (1)	CO ₂ + CH ₄ , H ₂ O	[164]
Kolar, India	235–340 (75)	-	0.57–1.24	700–6400 (24)	CO ₂ + CH ₄	[165]
Pamour, Canada	260–325 (7)	3.5–6.0	0.70–0.81	-	CO ₂ + CH ₄	[166]
Abbots, South Africa	242–319 (2)	6.4	0.74–0.87	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[167]
Bellevue, South Africa	233–314 (2)	4.8	0.75–0.87	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[167]
Pioneer, South Africa	195–307 (4)	1.8–8.5	0.73–0.93	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[167]
Surluga, Canada	180–300 (30)	1.0–23.0	0.90–1.01	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[168]
Sigma, Canada	113–425 (8)	1–40	-	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[169]
Donalda, Canada	100–380 (6)	4–41	-	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[169]
Dumont-Bras d’Or, Canada	175–398 (6)	-	-	-	CO ₂ + CH ₄ + N ₂	[169]
Champion lode, Kolar, India	138–421 (2)	29.2–49.8	1.08–1.14	3150–3600 (2)	CO ₂ , H ₂ O	[170]
Nundydroog mine, Kolar, India	170–440 (4)	5.0–30.0	0.86–1.13	-	CO ₂ , H ₂ O	[170]
Wiluna, W. Australia	243 (1)	23.2	1.02	-	H ₂ O	[171]
Bronzewing, W. Australia	103–445 (47)	0.2–26.0	0.76–1.14	-	CO ₂ + CH ₄ , CH ₄ , H ₂ O	[172]
Siscoe, Canada	156–330 (6)	2.0–9.0	0.67–0.98	-	CO ₂ + H ₂ O	[173]
Junction, W. Australia	69–400 (7)	8.8–42.0	0.63–1.07	700–4400 (2)	CO ₂ + CH ₄ , H ₂ O	[174]
Golden Eagle, Mosquito Creek belt, W. Australia	99–374 (10)	0.0–21.7	0.52–0.77	-	CO ₂ + CH ₄ , H ₂ O	[175]
Orenada 2, Canada	65–195 (8)	4.8–26.5	1.00–1.14	-	CO ₂ + CH ₄ , H ₂ O	[176]
Hutti, India	300 (2)	3.9–13.5	0.76–0.87	1000–1700 (2)	CO ₂	[177]
Golden Crown, W. Australia	257–376 (2)	2.3	0.48–0.82	500–3300 (6)	CO ₂ + H ₂ O	[178]
Wiluna, W. Australia	146–319 (3)	23.2–23.8	0.93–1.10	700–1680 (4)	CO ₂ , H ₂ O	[179]
Ramepuro, E. Finland	235–355 (3)	6.5–10.0	0.67–0.91	1000 (1)	CO ₂ + CH ₄ , CH ₄	[180]
Woodcutters field, W. Australia	210–462 (4)	5.7–14.1	0.76–0.90	-	CO ₂ , H ₂ O	[181]
McPhees, W. Australia	106–410 (9)	1.0–21.8	0.67–1.11	-	CO ₂ + CH ₄ + N ₂ , H ₂ O	[182]
Tarmoola, W. Australia	261–335 (8)	1.6–5.1	0.72–0.93	-	CO ₂ , H ₂ O	[183]
Mount Charlotte, Australia	220–312 (5)	4.5–5.7	0.74–0.89	1500–2200 (6)	CO ₂ + CH ₄ , H ₂ O	[184]
Giant, Canada	180–360 (4)	4.0–9.0	0.60–0.96	1000–2000 (2)	CO ₂ + CH ₄ , H ₂ O	[185]
Uti, India	180–397 (8)	0.5–22.0	0.55–1.01	930–2560 (4)	CO ₂ + H ₂ O	[186]
Primrose, Kwekwe, Zimbabwe	222–280 (6)	1.6–9.2	0.88–0.90	825–2780 (4)	CO ₂ , H ₂ O	[187]
Jojo, Kwekwe, Zimbabwe	145–219 (5)	-	0.97–0.99	990–3100 (4)	CO ₂ , H ₂ O	[187]
Indarama, Kwekwe, Zimbabwe	80–144 (3)	6.0–>22	1.02–1.23	1180–2850 (4)	CH ₄ + N ₂ , H ₂ O	[187]
Hutti, India	205–280	1.7–6.4	-	500–2000	CO ₂ + CH ₄ , H ₂ O	[188]
Hira-Buddini, India	128–320	0.5–22	0.67–1.09	-	CO ₂ + CH ₄ , H ₂ O	[188]
Sunrise Dam, W. Australia	198–433 (18)	3.0–21.4	0.67–0.90	800–2930 (19)	CO ₂ + H ₂ O	[189]
Missouri, W. Australia	61–402 (16)	3.0–26.0	0.90–1.01	420–2630 (30)	CO ₂ + CH ₄ + H ₂ S, CH ₄	[190]
Klipwal Gold Mine, South Africa	115–367 (316)	0.3–19.5	0.35–1.05	1100–2500 (4)	CO ₂ + CH ₄ , H ₂ O	[191]

Notes: * salinity of fluid expressed in wt% NaCl equiv.; ** composition of gas phase of fluid inclusions; Number of determinations is shown in parentheses.

4. Discussion

Tables 8 and 9 summarize data on fluid parameters of orogenic deposits of different age. The compiled dataset was analyzed using binary temperature–salinity and pressure–temperature diagrams,

histograms, and boxplot diagrams. In addition, the Student's t-test was calculated in pairs for salinity and fluid pressure values to compare the average values of independent data samples, since the distribution of fluid parameters did not differ much from the normal distribution. The principal conclusions derived from this analysis are discussed below.

The binary plots indicate that the data of all of the discussed deposit-age-groups plot within a single field, with the ranges of the parameters shrinking from older to younger deposits mostly because of progressively narrower ranges of fluid pressure and salinity (Figures 1 and 2). Some fluid parameters (salinity and pressure) systematically and notably vary depending on the age of the mineralization. At the same time, the homogeneous character of the fields and a single field for all data points of a given set indicate that the data are homogeneous (pertain to a single fluid system). This led us to suggest that most of the analyzed fluid systems belong to a single type: one that produces orogenic gold mineralization.

Table 8. Median values of main physicochemical parameters of mineral-forming fluids of orogenic gold deposits.

Age, Ma	Temperature, °C	Salinity, wt.% NaCl Equiv	n	Pressure, bar	n
Cenozoic 0–65	242 (128–424)	3.6 (0.0–19.6)	308	1305 (150–3600)	106
Mesozoic 65–252	260 (80–515)	5.9 (0.0–37.5)	1478	1200 (100–4000)	440
Paleozoic 2252–540	267 (70–550)	7.3 (0.1–49.0)	844	1500 (80–5030)	375
Meso- and Neoproterozoic 540–1600	255 85–454	10.0 (0.1–50.0)	181	1200 (120–3900)	55
Paleoproterozoic 1600–2500	252 (48–520)	7.1 (0.5–62.4)	465	2080 (500–6500)	57
Meso-Neoproterozoic 2500–3200	254 (50–462)	6.1 (0.0–49.8)	257	1680 (330–6400)	135

n: Number of determinations; Minimum and maximum values are shown in parentheses.

Table 9. Median values of main physicochemical parameters of mineral-forming fluids of large (≥100 tonnes Au) orogenic gold deposits.

Age, Ma	Temperature, °C	Salinity, wt.% NaCl Equiv	n	Pressure, bar	n
Cenozoic 0–65	255 (140–424)	3.7 (0.5–14.6)	58	1335 (500–3400)	17
Mesozoic 65–252	277 (80–515)	5.8 (0.01–37.5)	585	1220 (190–3380)	206
Paleozoic 252–540	280 (80–550)	7.7 (0.2–28.3)	342	1590 (150–3460)	133
Meso- and Neoproterozoic 540–1600	275 (143–454)	14.2 (1.0–50.0)	51	1200 (120–3900)	54
Paleoproterozoic 1600–2500	221 (48–510)	13.2 (0.5–62.4)	89	1500 (1250–2800)	5
Meso-Neoproterozoic 2500–3200	280 (60–462)	7.0 (0.1–49.8)	69	2100 (700–6400)	49

n: Number of determinations; Minimum and maximum values are shown in parentheses.

The histograms of the fluid homogenization temperatures (Figure 3) are unimodal, which also indicates that the dataset is homogeneous. They also show that the temperature range of homogenization temperatures widens from the younger to older deposits.

Fluid salinity (Figure 4) also shows unimodal distribution. The histograms for the Meso- and Neoarchean and Neoproterozoic show a very weak tendency toward bimodality, but the sets of data on these deposits are the smallest, and hence, the bimodality of these diagrams may be explained simply by the scarcity of the data in each of the sets. The salinity range generally widens with increasing age of the fluids, as also do the maximum salinity values. The histograms are skewed, with the maxima occurring in the regions of the minimum salinity values.

The pressure histograms (Figure 5) are generally also skewed unimodal, with maxima within the range of 500–2000 bar. Data on the Precambrian deposits are obviously scarcer than those on Phanerozoic ones. The maximum pressure values generally tend to increase from the younger to older deposits, which widens the range of the pressure values.

The boxplot diagrams provide more information for analysis of the distribution because they display the region in which half of the values plot and the maximum and minimum parameters, outliers, and the median and average values. For the temperature (Figure 6), most of the determined values obviously lie within the range of 200 to 300 °C. The medians, Q25 (first quartile), Q75 (third quartile), and the maximum homogenization temperature values slightly increase from the Cenozoic to Paleozoic. Simultaneously the ranges of the maximum and minimum values widen. No such tendencies were detected for the Precambrian fluids, but the ranges of all of the boundary values are similar. We detected small outliers only for the data on the Mesozoic and Paleozoic, which indicates that the whole dataset is homogeneous. The facts presented above seem to indicate that the orogenic fluid systems are thermostated, perhaps, because of their flow-through character.

The boxplot diagram for the salinity values (Figure 7) shows that most of these values group in the range of moderate concentrations and do not exceed 18 wt.%. However, the overall range of the concentrations is roughly twice as large, and some outliers correspond to even greater salinity values. It is interesting that the salinity values statistically significantly increase with increasing age of the deposits. This is seen in the monotonous increase in the median values, Q75, the maximum ranges, and the maximum outliers. The overall tendencies are slightly disturbed by data on the Meso- and Neoproterozoic, which define a local maximum, and by data of the Meso- and Neoarchean, which define a local minimum. However, as was mentioned above, these time periods are characterized by the smallest amounts of data. The deviations from the general tendency may be explained simply by the insufficiency of the factual material.

The boxplot diagram for the fluid pressures (Figure 8) shows that most of the pressure values almost do not vary and group within the range of 500 to 2500 bar. However, comparison of the maximum variation ranges and the maximum outliers shows a general increase in these parameters with increasing age of the deposits. The general tendency is slightly disturbed by data on the Meso- and Neoproterozoic and on the Meso- and Neoarchean, which define a local minimum. However, these time spans are characterized by scarce data (see above). The same conclusion is derived from the analysis of the median pressure values.

The results of the calculation of Student's t-test for comparing the average values of fluid salinity and pressure, performed in pairs for all combinations, showed statistically significant differences between all samples under consideration. Below for an example are the results of an independent-samples Student's t-test for comparison of characteristics of Cenozoic and Paleoproterozoic fluids. The significant difference was revealed between the scores of salinity values for Cenozoic and Paleoproterozoic fluids: mean value $M = 4.29$ wt.%, standard deviation $SD = 0.168$ and $M = 9.208$ wt.%, $SD = 0.395$, respectively; Student t-test for this pair $t(771) = 11.47$, and significance $p = 0.00000$. The obtained t value is significantly higher than the critical value of the Student t-test, which is 1.972, at a significance level of $\alpha = 0.05$. These results show that the difference in Cenozoic and Paleoproterozoic average salinity values is statistically significant.

An analogous calculation was performed to compare values of pressure of Cenozoic and Paleoproterozoic fluids. The significant difference also was found in the scores of pressure values for Cenozoic and Paleoproterozoic fluids ($M = 1380$ bar, $SD = 77.75$) and ($M = 2577$ bar, $SD = 187.50$), respectively; $t(161) = 5.90$, $p = 0.00000$. The obtained t value, as in the previous case, greatly exceeds the critical value of the Student's t -test, which is equal to 1.975, at a significance level $\alpha = 0.05$. This proves that the differences in the mean pressures of the Cenozoic and Paleoproterozoic fluids are statistically significant.

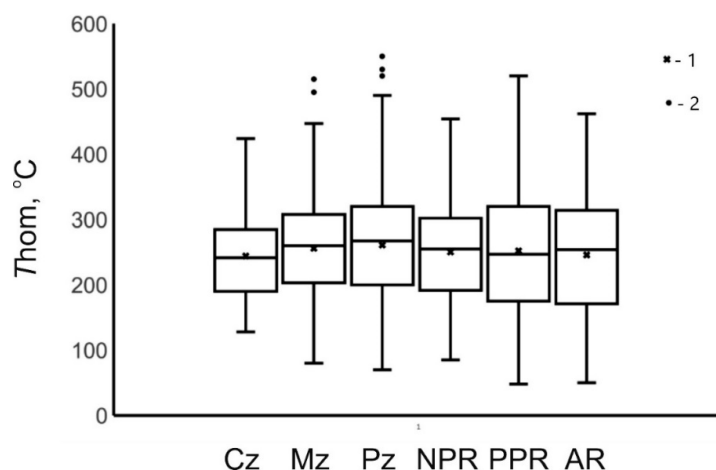


Figure 6. Boxplot diagrams for the temperatures of the mineralizing fluids of orogenic gold deposits of various age. Here and in Figures 7 and 8: Cz—Cenozoic; Mz—Mesozoic; Pz—Paleozoic; NPR—Mesozoic and Neoproterozoic, Paleoproterozoic; AR—Meso-Neoarchean; 1—average; 2—outliers.

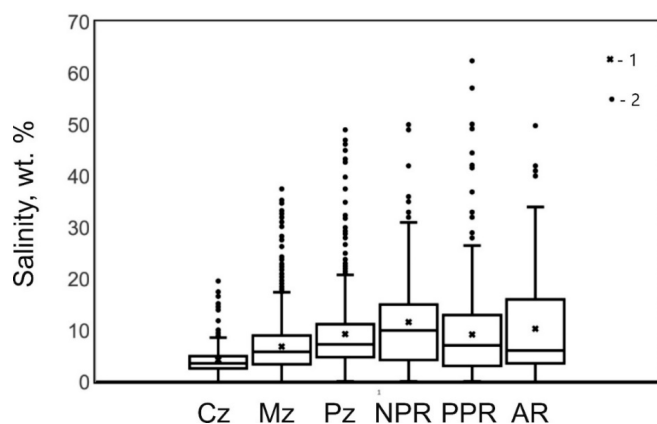


Figure 7. Boxplot diagrams for the salinity of the mineralizing fluids of orogenic gold deposits of various age.

We did not detect any differences in the parameters of fluids from the large deposits relative to those from the smaller ones (Table 9).

In considering information not shown in the diagrams but discussed in literature following three types of fluid can be distinguished: (1) heterogeneous fluid, which is mixture of dense gaseous fluid and liquid aqueous salt fluid; (2) homogeneous aqueous salt fluid; and (3) homogeneous dense gaseous fluid, which can contain variable proportions of CO_2 , CH_4 , and N_2 . The phase composition of the fluids seems to also correlate with the age. The fluids at the young deposits correspond to types (1) and (2), whereas fluids at the Precambrian deposits can be of any of the three type.

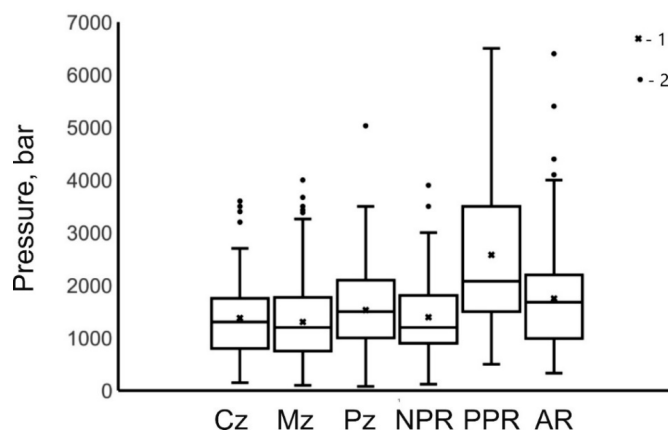


Figure 8. Boxplot diagrams for the pressure of the mineralizing fluids of orogenic gold deposits of various age.

Orogenic gold deposits are major exploration targets and global gold producers, and are thus actively studied using various microanalytical techniques. In addition to hundreds of papers on the fluid regime of individual gold deposits, three significant reviews have been published on fluid inclusion features of orogenic gold deposits worldwide [4,192,193].

A principal conclusion formulated by [192] can be summarized as that orogenic gold deposits are produced from heterogeneous fluids consisting of a high-density gas phase, dominantly CO_2 , and an aqueous solution with relatively low salt concentrations. This conclusion generally does not contradict our analysis and most of the orogenic gold deposits evaluated here some 20 years later continue to show these features. However, a notable number of the deposits were formed from a homogeneous fluid. Moreover, some orogenic gold deposits were generated from chloride brines (e.g., Gara and Yalea, Mali; Telfer, Australia; Irokinda, Russia). This provides evidence to argue that a heterogeneous ore-forming fluid and a low salinity may not necessarily be inherent to fluids required to form orogenic gold deposits.

Another review [4] is even more extensive, but the principal conclusions remain the same. This review suggests that trapped chlorine brines these are low-temperature fluid inclusions that are not related to the ore-forming process but rather reflect the influx of pore water solutions into the hydrothermal system. Based on our comprehensive review of the existing literature, we argue that fluid inclusions with high-temperature chloride brines documented at some of the deposits (Gara and Yalea, Mali; Telfer, Australia; Irokinda, Russia; etc.) were trapped when the host quartz crystallized simultaneously with the native gold. These more saline ore fluids are also not equally observed in deposits of different ages but appear to be significant only during certain epochs. It is also reasonable to suggest that the ability of fluid at orogenic gold deposits to carry gold only insignificantly depends on the chemical composition of this fluid. Indeed, both chloride and hydrocarbonate (containing CO_2 and CH_4) fluids were found in variable proportions (up to the dominance of either the oxidized or the reduced species) at the deposits.

Key-idea idea stressed throughout the third review [193] is that the composition of the inclusions may have changed during the post-mineral history of the mineralization, when the deposits were exhumed. These changes may reflect both post-entrapment modifications of fluid inclusions (e.g., necking, leakage, etc.) or overprinting by of later generations of secondary inclusions during the exhumation. This is an important conclusion, which undoubtedly requires consideration for a meaningful interpretation of fluid inclusion data. However, the more reliable publications on fluid inclusions, to which our review is devoted, soundly demonstrate compiled data reflect the ore-forming process. It is thus reasonable to suggest that the evaluated parameters here do pertain to the origin of the gold ores and not to post-ore processes. The other important conclusion that follows from analysis

of the paper by [194], which reviews both data on fluid inclusions and stable isotopes, is that the orogenic gold ore-forming fluids may have originated from more than one crustal source reservoir.

Our data generally do not contradict earlier reviews [4,192,193] and slightly append them. At the same time, the detected statistically significant differences in some parameters of mineralizing fluids at orogenic gold deposits of different age is principally new information, which deserves adequate understanding.

We think that it is hardly probable that similar hydrothermal processes that produced deposits of the same genetic type could principally change through the Earth's history. Analysis of geological descriptions in all of the publications indicates that there were no cardinal differences between the geological structures of orogenic deposits formed at different time. These are commonly vein- or stringer-hosted gold mineralization in sedimentary or metamorphic rocks. The metamorphic rocks are usually metamorphosed to the greenschist or, sometimes (for the Archean deposits) amphibolite facies.

To understand the trends and relations described above, one has to recall that orogenic fluid systems operate within a broad range of depths: from a few to 25 km [1,2], and the deposits are now variably exhumed and eroded. This is in good agreement with the current model of orogenic gold deposits (Figure 9) [194]. The depths of erosion of younger deposits are, in general, shallower than those of older deposits, as was demonstrated using extensive information in [195], a paper aimed to explain why there are no ancient epithermal deposits. Epithermal deposits are formed at shallow depths, whereas orogenic deposits were produced at much greater ones. Because of this, most Cenozoic gold deposits occur at various depths, and only some of them are exposed by erosion in areas of young orogenic processes (for example, in Tibet). The older an orogenic gold deposit, the greater depth of its erosion. Archean deposits in India are eroded to the greatest depths and are the world's deepest orogenic gold deposits ("hypozonal" according to [194]). Fluid pressures higher than 6 kbar were detected at these deposits [165]. In addition, one shall keep in mind that our statistical analysis of fluid parameters was carried out for fairly long-time spans. The depths of erosion of the deposits of each of the age groups can thus significantly vary and, hence, also affect the scatter of parameters within the groups. Because of this, statistically significant values in the boxplots are not the maximum parameters in the ranges but also outliers.

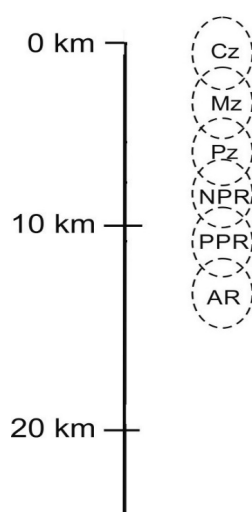


Figure 9. The average levels of exhumation of orogenic gold deposits of different ages.

There can be different reasons for the increase in the salinity of fluids at orogenic deposits with depth. It is pertinent to recall that deep crustal high-temperature and high-pressure zones typically host chloride brines as pore waters [196]. This sheds light on why they are recognized in the deeper parts of orogenic gold fluid systems, as is reflected in the occurrence of brine-bearing fluid inclusions in the older gold deposits. At shallower levels, the systems may also undergo input of less mineralized

fluids of a different nature. Another possible explanation of the occurrence of high-temperature brines in orogenic fluid systems may be the involvement of magmatic fluids in the mineral-forming processes [153].

We believe that the aforementioned differences we detected between parameters and composition of mineral-forming fluids at orogenic gold deposits reflect the vertical zoning of the mineralizing fluid systems of orogenic gold deposits. This zoning can remain unidentified or ignored when a single deposit is studied, but it becomes quite obvious when the whole ranges of the parameters of such deposits are studied. This zoning has nevertheless never been mentioned before with reference to orogenic mineralizing systems and shall be taken into account when these deposits are studied.

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Author Contributions: V.Y.P.—the idea of the article, the grouping of deposits by the time of their formation, statistical processing and writing of the text. V.B.N.—browse the literature, select the necessary publications, fill out the database. All authors have read and agreed to the published version of the manuscript.

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