TAKING THE WATERS? : SHARGALJUUT HOT SPRINGS (MONGOLIA)

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SUMMARY - The Shargaljuut hot springs, ~680km west of Ulaan Baatar (Mongolia), are utilised for their medicinal qualities. Thermal features at Shargaljuut comprise steaming ground and low-flow springs (0.1-2 Vsec), which discharge hot (up to 90.5°C), 8.2-8.7 pH, low Cl (<1mg/kg), weakly mineralised (<44mg/kg SiO_2, <13mg/kg $HCO_{3\,(total)}$) waters. Shallow drilling indicates a water "reservoir" at 50-60m depth, whilst solute geothermometry points to deeper <160°C fluids. The source of the geothermal energy could be conductive heat associated with the "Mongolian Hot Spot", which is transferred through overlying Palaeozoic metasediments and igneous rocks, to heat near surface meteoric waters.

1. INTRODUCTION

There are numerous hot springs in Mongolia, and many are utilized for cooking, heating and medicinal purposes. One thermal area, known for more than 300 years and developed in 1962 as a year-round National Sanatorium, is the Shargaljuut Hot Springs, although little has been published on the nature and chemistry of its thermal waters.

Each year, the Shargaljuut Sanatorium receives >3000 visitors from Mongolia and central Asia, due the "invigorating qualities" of the thermal waters, which are effective for those with "contagious skin diseases, high blood pressure, rheumatic fever, liver or stomach complaints, or problems with the nervous system". The complex, utilises thermal waters for bathing and traditional cooking, and now boasts its own cinema, post office, library, restaurants and hotel.

Hot and cold spring waters flow from several locations at Shargaljuut and these have reportedly "changed over the years", almost certainly due to wasteful extraction of an undetermined volume of thermal fluid for use in the sanatorium, as well as natural discharge to the nearby Shargaljuut River.

Mongolia, and her people, utilise their geothermal resources in a different way to New Zealand, but Shargaljuut is also a reminder of the damage that can be caused to any hot spring system, by poorly managed resource development. This paper describes the present extent of thermal activity at Shargaljuut, and the chemistry of its hot springs, and will enable future changes in the geothermal system to be better recognised.

2. LOCATION, ACCESS AND CLIMATE

Shargaljuut (Long: 101” 13’20-36"E; Lat: 46° 19’ 50" - 20' 03"N) is located 42km from Erdenetsogt sum in the Bayankhongor Prefecture, ~680km by paved (mostly) road west of Ulaan Baatar (Fig. 1).

The Shargaljuut hot springs occur in the NNE-SSW oriented Shargaljuut Valley, within the Khangai Mountain Range (the highest point is Ugalz Gol, at 2803 mRSL). The Shargaljuut hot springs, adjacent to the 10-30m wide/0.6m deep Shargaljuut River, occur at ~2120 mRSL (Fig 2).

The climate in the Shargaljuut area is harsh, with winter temperatures of -23 to -27°C, and deep snowfall (up to several metres) that begins at the end of August and remains on the ground to May. Summers are mild, with temperatures reaching 17 to 22°C in July and August, which coincides with most of the annual rainfall (average precipitation is 250-300mm/yr).

Fig. 1: Location map of Shargaljuut, Mongolia

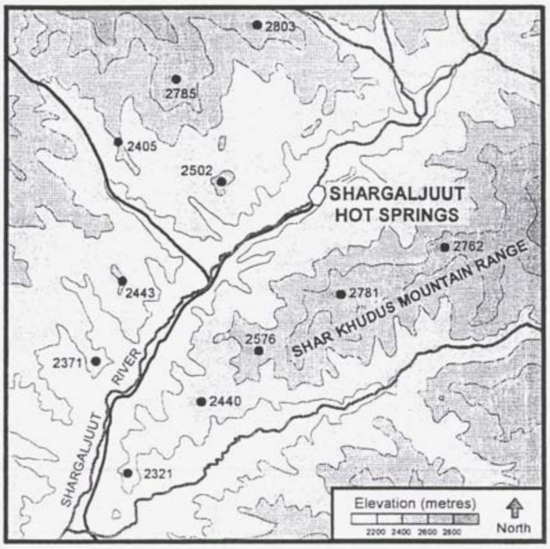

Fig 2: Map of Shargaljuut area, showing location of thermal features, streams and local relief.

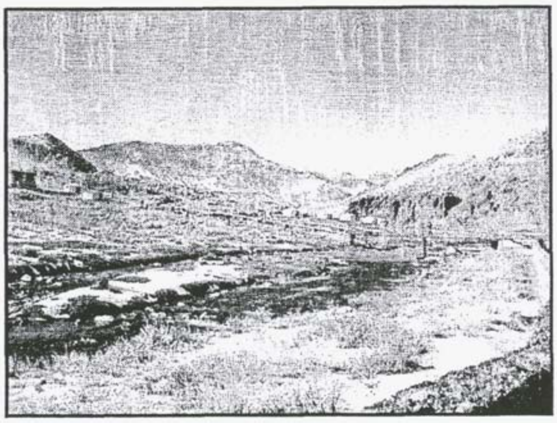

Fig 3. Shargaljuut Valley, with the hot spring area in middle-ground (huts placed over some springs).

3. REGIONAL GEOLOGY

The geology of the Shargaljuut area comprises Devonian sedimentary units, Upper Carboniferous granite and quartz-diorite, which are covered by unconsolidated Quaternary sediments (Uflyand *et al.,* 1966; in Lhagva 1975).

The Devonian Erdenetsogt Formation consists of alternating siltstone-sandstone units. The 1500-2000m thick Erdenetsogt Formation crops out SW of Shargaljuut, and to the NE of the hot spring area, where its occurrence is fault controlled.

Upper carboniferous granitoid rocks are common, and intrude the older sedimentary unit. Intrusive rocks include leucocratic biotite-hornblende granite, quartz-diorite and granodiorite. Near the Shargaljuut River, granite is hydrothermally altered, with conspicuous epidote alteration. Quartz veining also occurs, associated with weak malachite, hematite and sphalerite mineralization.

The Quaternary deposits comprise 0.5-2m thick deluvial sequences, 4-5m thick alluvial deposits (well rounded gravel and clay) and proluvial material (<10m thick; sandstone, coarse-grained clay and poorly sorted/subround gravel).

The Shargaljuut area is situated within the Innerbaikal-Mongolian fold belt (Hasin, 1971; in Lhagva 1975), which is characterized by NE - SW trending faults (subparallel to the Shargaljuut valley) and cross-cutting NW faults. Hot spring locations at Shargaljuut are coincident with the intersection of the two fault sets.

4. THERMAL FEATURES

Thermal features at Shargaljuut cover a wide area, with hot and cold spring waters discharging from several locations, whilst the stony hillside facing the Shargaljuut Sanatorium steams effusively. The cold springs are used as a source of domestic drinking water and for watering farm animals, whilst the Baga Shargaljuut and Taats Sharga hot springs are also located nearby.

The thermal manifestations at Shargaljuut were surveyed at a reconnaissance-level (and water (spring) samples were also collected), during a September 2002 visit, as part of a (ongoing) study at Tohoku University to understand fluid-rock interactions in the geothermal setting.

Odourless, near boiling hot waters discharge at Shargaljuut over an area of about 0.5km^2, mainly from small cracks in discoloured, lichen-covered metamorphosed sandstone and intrusive rocks (with flow rates up to 5l/min, although most discharge at 0.2 – 2 l/min) and from loose alluvial sand and gravel in the Shargaljuut River.

Most spring waters at Shargaljuut range in temperature from 45°C close to the Shargaljuut River (at about 2150mRSL, where they are mixed with rain and river water), and 98°C further away from the river (at higher elevation); Figs 3 and 4.

Thin, translucent to white opaque silica sinter coat rock surfaces around most springs on the hillside above the Shargaljuut Sanatorium, but is not evident where warm (near-neutral pH, colourless, and odourless) waters seep out of the loose sedimentary units.

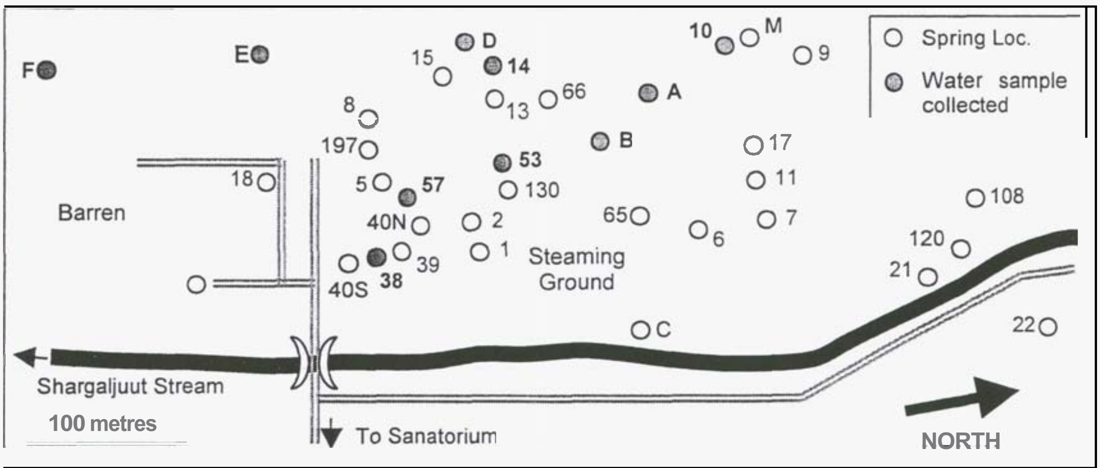

Fig 4. Location map of Shargaljuut hot springs (including springs sampled for geochemical analysis).

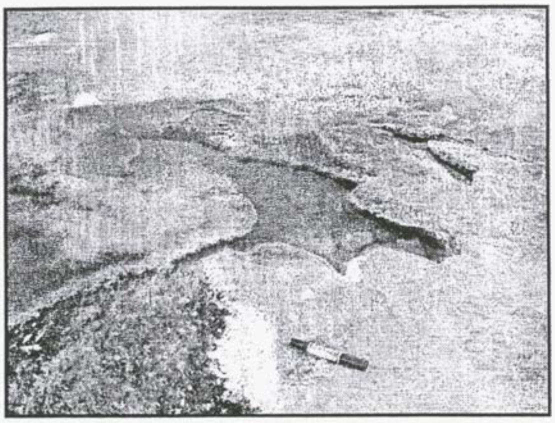

Fig 5. Crusty amorphous silica sinter surrounds a warm spring (N38, 57°C, 8.4pH), Shargaljuut.

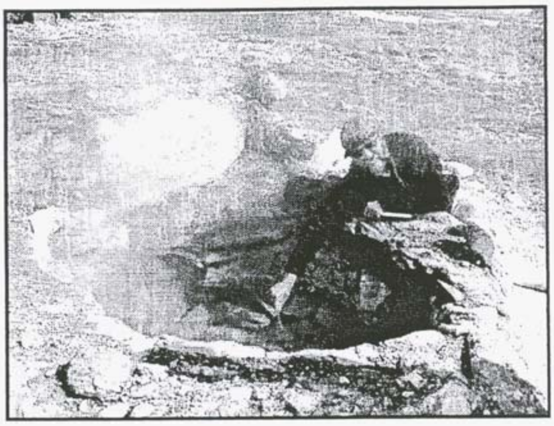

Fig 6. Spring "F" (86°C, 8.6 pH) had the greatest flow rate (~4 l/sec) of sampled Shargaljuut springs.

5. WATER CHEMISTRY

Water samples were collected from 10 hot springs and pools, during a brief visit to Shargaljuut in September 2002. Five of the thermal features (N10, N14, N38, N53 and N57) are utilised by the Shargaljuut sanatorium for their medicinal qualities, and an additional five (previously unnamed) springs were sampled ("A", "B", "D", "E" and "F").

Only springs with high flow rates (unlike most of the hot springs at Shargaljuut) were sampled, using standard water sampling practices. For the first time, the precise location of thermal features at Shargaljuut was established by GPS (Table 1).

Water temperature and pH (using pH paper) were measured in the field by the authors, with chemical constituents in the water samples determined by Dr. Junko Hara (Graduate School of Environmental Studies), using high-sensitivity ion-chromatography (Hitachi L-7000), TOC (Shimadzu 5000A; for $HCO_{3(Total)}$) and ICP-AES (Hitachi P-4000), as appropriate.

The results of the chemical analyses of the thermal waters are listed in Table 2, and plotted (together with typical geothermal water-types) on Fig. 7.

Table 1: Location of Shargaljuut Hot Springs

Spring		T (°C)	LAT (N)	LONG (E)
M	Mud Pool	7	46° 20' 03.2"	101° 13'29.4"
N1	warm spring	63	46' 19'56.7"	101° 13'33.7"
N6	warm spring	-	46' 19'57.5"	101° 13'34.4"
N10	hot spring	80	46' 20' 03.1"	101° 13'30.6"
N13	warm spring	40	46° 19'58.5"	101° 13'30.8"
N14	hotspring	82	46' 19'58.6"	101° 13'30.6"
N38	warm spring	57	46' 19'55.9"	101° 13'33.8"
N53	warm spring	50	46' 19'57.2"	101'13'33.3"
A	hot spring	86	46' 20'01.6"	101'13'31.3"
B	hot spring	90.5	46' 20'00.7"	101° 13'32.1"
C	hot spring	67	46' 19'58.5"	101° 13'36.3"
D	hotspring	89	46° 19'58.0	101'13'29.6"
E	hot spring	88	46° 19'54.7"	101° 13'27.6"
F	hot spring	86	46' 19'50.4"	101° 13' 24.9"

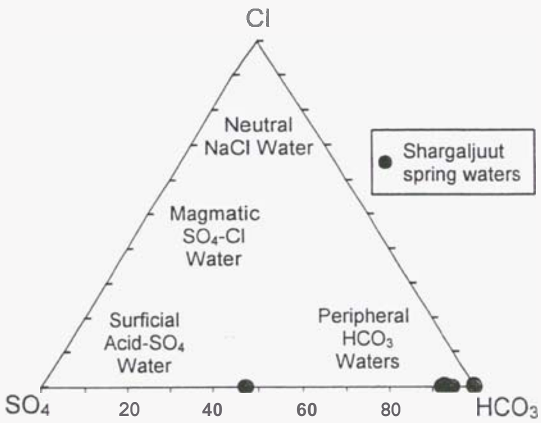

Fig 7: Cl-SO_4-HCO_3 plot of Shargaljuut waters

Table 2: Chemistry of spring waters, Shargaljuut Hot Springs

Spring	Type	Temp (°C)	Flow l/s	pH	Li	Na	K	Al	Ca	Mg	Fe mg/kg	Cl	F	Br	SO_4	HCO_3 (total)	SiO_2	NH_4	NO_2	TDS
N10	hot spring	80	<1	8.2	0.46	64.1	1.7	0.6	2.4	<0.1	<0.1	0.0	0.05	0.56	-	12.3	43.5	-	-	130
N14	hot spring	82	1-2	8.6	0.53	84.4	1.7	0.6	1.8	<0.1	<0.1	0.0	-	0.02	0.0	10.9	39.2	-	0.06	140
N38	warm spring	57	<1	8.4	0.54	89.3	1.7	0.6	1.7	<0.1	<0.1	0.6	1.37	-	5.6	11.5	39.1	-	-	150
N53	warm spring	50	<1	8.4	0.51	74.7	1.8	0.6	1.9	<0.1	<0.1	0.1	0.22	-	0.8	11.5	41.1	-	-	130
N57	hot spring	67	<1	8.3	0.51	85.4	1.1	0.6	1.6	<0.1	<0.1	0.1	-	0.20	-	11.0	38.5	-	-	140
A	hot spring	86	3-4	8.2	0.49	70.3	1.7	0.6	2.1	<0.1	<0.1	0.0	0.04	-	1.0	12.4	42.2	-	-	130
B	hot spring	90.5	3-4	8.4	0.51	88.2	1.3	0.6	1.8	<0.1	<0.1	0.0	-	-	0.7	11.2	40.8	-	-	140
D	hot spring	89	1	8.6	0.48	71.4	1.4	0.6	2.2	<0.1	<0.1	0.0	-	-	0.7	12.0	44.0	-	-	130
E	hot spring	88	1	8.7	0.47	62.5	1.8	0.6	2.4	<0.1	<0.1	0.0	-	0.41	0.0	12.6	43.6	-	-	120
F	hot spring	86	4	8.6	0.50	69.1	1.9	0.6	2.4	<0.1	<0.1	0.0	-	-	-	12.8	44.2	-	0.67	130

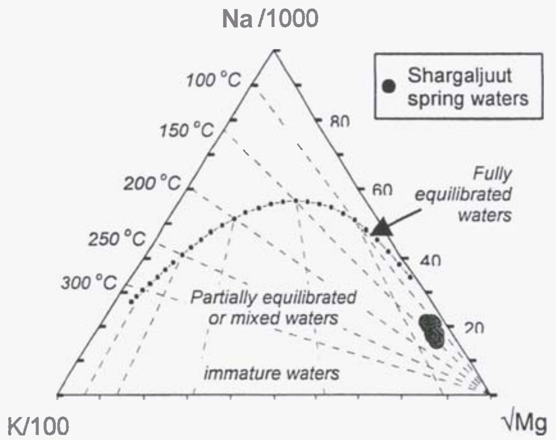

Fig 8: WlOO - Na/1000 - √Mg plot of spring waters at Shargaljuut, after Giggenbach (1988).

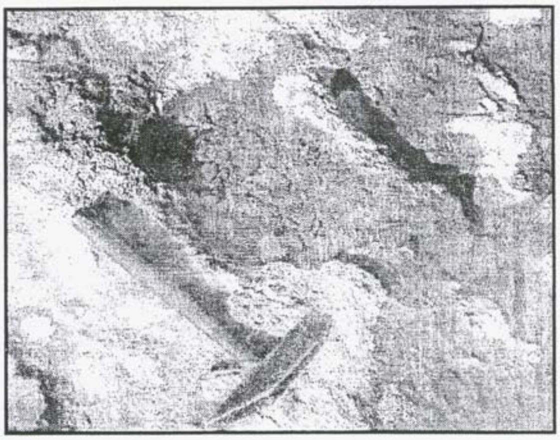

Fig 9: Most springs at Shargaljuut have low flow rates (<1 l/sec); e.g. N10, 80°C, 8.2 pH (above).

In an earlier survey, Lhagva (1975) indicated waters discharging from cracks in Palaeozoic sedimentary rocks at Shargaljuut had a chemical composition of "Mn 0.006-0.1%, Ni 0.001-0.004%, Cu 0.001-0.005%, Cr 0.01-0.04%, Ag 0.0008-0.002%, Sn 0.001-0.004%, Ti 0.01-0.02%, Pb 0.001-0.003%, Sr 0.01-0.03%, Zn 0.008-0.0 1%". Most springs flowed at 0.1-2 l/sec, with a few at 3-4 l/sec. Shallow drilling (to supply water to the Shargaljuut sanatorium) indicated a hot water "reservoir" at 50-60m depth – no core or rock cuttings from the shallow drilling programme were available for examination during this study.

In addition, Lhagva (1975) suggested water discharging from cracks in igneous rocks were "Na-Ca, hydrocarbonate Ca-Na-Mg and hydro-carbonate SO_4-Na in composition" and "weakly mineralized". In contrast, waters seeping from unconsolidated Quaternary sediments were "hydrocarbonate Na-Ca water", with "mineralization of 0.4g/l and PH<7."

The present chemical survey shows that the Shargaljuut springs, sampled in September 2002, continue to discharge dilute, non-mineralised (although transporting sufficient SiO_2 to deposit silica sinter around most springs), steam-heated (<90.5°C), neutral pH (or slightly alkaline) waters.

Table 3: Geothermometry

Spring		T (°C)	QTZ	CHAL	NaK	NaKCa
N10	hot spring	80	95	65	126	83
N14	hot spring	82	91	60	109	91
N38	warm spring	57	91	60	107	94
N53	warm spring	50	93	62	119	91
N57	hot spring	67	90	59	86	79
A	hot spring	86	94	64	120	86
B	hot spring	90.5	93	63	93	82
D	hot spring	89	96	66	107	78
E	hot spring	88	96	65	129	83
F	hot spring	86	96	66	127	86

QTZ (quartz, conductive cooling) and CHAL (chalcedony), Fournier, 1981; NaK (Fournier, 1979); Na-K-Ca (Fournier and Truesdell, 1973).

The major element chemistry of Shargaljuut spring waters (<90 mg/kg Na, 44 mg/kg SiO_2 and 13 mg/kg $HCO_{3\ (total)}$) reflects the interaction of heated meteoric water (rain and melted snow), with Palaeozoic sedimentary and igneous rocks.

Solute geothermometry (quartz, chalcedony, Na/K (after Fournier, 1979) and Na-K-Ca (Fournier and Truesdell, 1973)) has been used to estimate the subsurface temperature of fluids supplying surface manifestations at Shargaljuut. Although the springs fail to satisfy typical criteria for application of solute geothermometry (they are low flow rate, non-boiling (although up to 90.5°C) low Cl springs), the results are consistent and point toward a fluid source of <130°C (Table 3).

Shargaljuut spring waters plotted on a K/100 – Na/1000 – √Mg diagram (after Giggenbach, 1988), indicate a fluid source of < 160°C.

6. SHARGALJUUT HOT SPRING SYSTEM

The Shargaljuut hot spring area is located in rugged, mountainous terrain, with a large area of steaming ground and numerous hot springs. The manner, however, that local people utilise hot waters discharging at Shargaljuut is quite different to traditional bathing, cooking and energy utilisation in Japan, New Zealand and elsewhere.

Unlike active geothermal systems in New Zealand, Japan, and elsewhere, there is no ***obvious*** heat source for thermal manifestations at Shargaljuut, or for the nearby Baga Shargaljuut, Taats Sharga, Ugalz gol hot springs - i.e. there' are no active or recently active volcanoes in the area and large scale active faulting is not a convincing means of generating sufficient heat for the large number of thermal areas (many with near-boiling hot springs).

Researchers at the Mongolian University of Science and Technology have proposed the presence of the "Mongolian Hot Spot" in the Khangai area (pers. com.), and it is possible that the source of geothermal energy is conductive heat from magma associated with the "Hot Spot", which is transferred through overlying Palaeozoic metamorphosed sediments and igneous rocks, to heat rainwater and melted snow in the near surface (Bignall *et al.*, submitted). Dorjderem (unpubl. report, 1995) has suggested a "deep", 150-180°C water reservoir at ~300m depth (although solute geothermometry in this study indicates a fluid source of no more than 130-140°C).

The upwelling waters react with Palaeozoic rocks in the Shargaljuut area, and are channelled to the surface via NE-SW and cross-cutting NW faults. The weakly mineralised waters finally discharge fiom cracks in the metamorphosed rocks, with low flow-rate from the Shargaljuut springs (about 50-60 Vsec over the entire thermal area; Dorjderem, 1995) attributed to the amount of past rain and snow fall in the Khangai area.

7. MEDICINAL (AND OTHER) USES

Mongolia is a land-locked country, sharing borders with P.R. China and Russia. It depends on traditional, non-renewable sources of energy for almost all of its electrical power. At present, Mongolia has no geothermal power generation, and there are few rivers suitable for hydroelectric power stations, so renewable energy resources supply only a very small percentage of its primary energy requirements.

For centuries, Mongolian people have used hot springs to supply baths and heat associated buildings, although most development has been to utilise the thermal waters for their therapeutic properties. There is potential to develop hot spring areas as part of expanding tourism to the country.

The Shargaljuut hot springs have been known for more than 300 years, and a year-round National Sanatorium was established there in 1962 (Fig 10). Now, the Shargaljuut Sanatorium receives >3000 annual visitors, who benefit from the "invigorating qualities" of the thermal waters (Table 4).

Table 4: Health benefits from Shargaljuut waters

Spring	Type	Temp (°C)	Health Benefits:
N2	warmspring	70	Small and large intestines
N5	warmspring	60	Brain and spinal cord
N6	hotspring	87	Gynaecological matters
N7	warmspring	80	Mind and intellect
N10	hotspring	80	Feet and legs
N13	warm spring	40	Stomach (to reduce stomach acid)
N14	hot spring	82	Stomach (increase stomach acid)
N15	hot spring	70	Throat (infection)
N17	warmspring	45	Erythrocytes (red blood cells?)
N37	hotspring	-	Ear
N38	warmspring	57	"To refresh 5 senses"
N39	warmspring	58	Nose
N40	warm spring	40	Gastrointestinal conditions / Kidney
N53	warmspring	50	Eyes
N57	warmspring	57	Teeth
N66	hotspring	80	Rheumatism

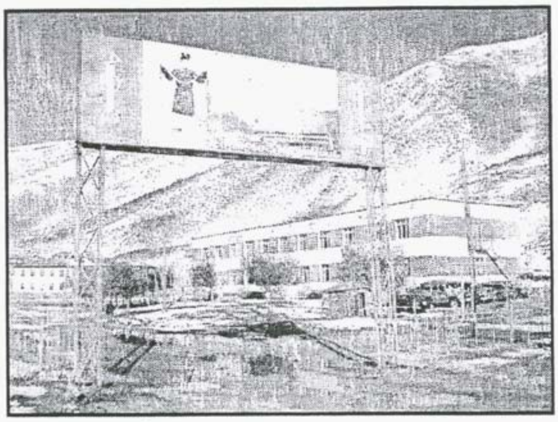

Fig 10. Shargaljuut Sanatorium utilises thermal waters for their medicinal qualities. Visitors to the Shargaljuut Sanatorium believe the waters provide effective relief for "contagious skin diseases, high blood pressure, rheumatic fever, liver or stomach complaints, or problems with the nervous system".

Fig 11. "Taking the Waters". Typically, thermal waters at Shargaljuut are drunk – in the case of Spring N40 (86°C, shown above), to improve gastrointestinal conditions.

Fig 12. Some Shargaljuut springs are covered by a wooden structure, with holes for asthma suffers to breath the "vapours" (mostly steam) – visitors also collect the steam in glass jars and drink the condensed water.

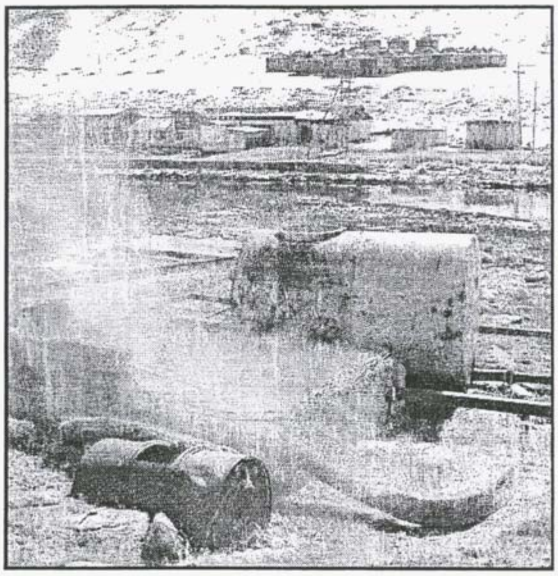

Fig 13: Shallow drilling at Shargaljuut has been undertaken to supply hot water to the nearby sanatorium. This is wasteful exploitation, as most of the water spills into the Shargaljuut River.

One feature of Mongolian thermal areas, is the way that their medicinal or recreational qualities are utilised. At Shargaljuut, a visit to the thermal area does not conclude with a "bath". Here, the medicinal qualities of the hot waters are best utilised by drinking the water (Fig. 11), or "breathing the vapours" (Fig. 12). In both instances, the waters reputedly provide a wide range of beneficial qualities (Table 4).

9. SUMMARY

1. There are numerous hot springs in Mongolia, and many are utilized for agricultural, heating and medicinal purposes, but the country has no geothermal power generation.

2. Shargaljuut is located ~680km west of Ulaan Baatar, and its springs are visited by hundreds of people each year to benefit from the waters "invigorating (medicinal) qualities".

3. Thermal features at Shargaljuut comprise steaming ground and numerous low flow (typically <2 l/sec) springs, which discharge hot (< 90.5°C), 8.2-8.7 pH, low Cl (<1mg/kg), weakly mineralised (<90 mg/kg Na, <44 mg/kg SiO_2 and 13 mg/kg $HCO_{3\,(total)}$) waters.

4. Shallow drilling at Shargaljuut has indicated a water "reservoir" at 50-60m depth, but subsequent studies have suggested a 300m source (of <160°C water).

5. The source of the geothermal energy could be conductive heat from magma associated with the "Mongolian Hot Spot", which is transferred through Palaeozoic metasediments and igneous rocks, to heat near surface meteoric water.

6. To date, little has been published about the active geothermal systems in Mongolia, and many areas have not been studied in detail. Consequently, many opportunities exist to undertake a range of exploration programmes to (i) determine their (geochemical) character and resource potential of known fields, and (ii) delineate new thermal areas.

10. ACKNOWLEDGEMENTS

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