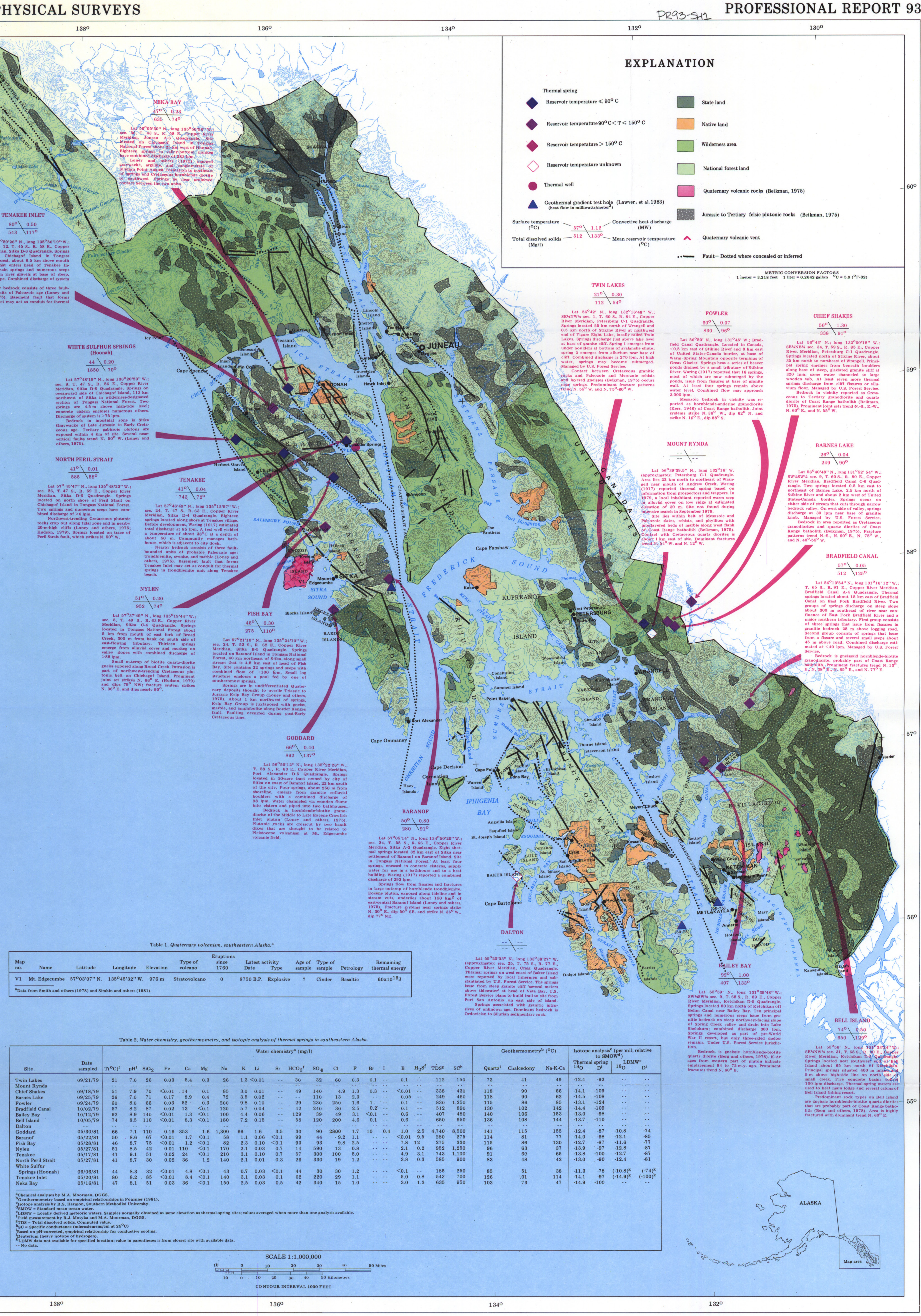

INTRODUCTION

The presently known geothermal-resource base for southeastern Alaska consists of the young igneous system at Mt. Edgecumbe and 18 hot-spring sites along the length of the Alaska panhandle. Many of the sites were first reported by Waring (1917) and later summarized by Miller (1973). Several sites reported but not substantiated by Waring could not be found by DGGS and are presently discounted. Three sites—Nylen, Bradfield Canal, and Barnes Lake—were recently discovered and are described below.

Thermal springs are the surface manifestations of subsurface hydrothermal systems. In such systems, heat is transported primarily by convective circulation of fluids (usually water) rather than by thermal conduction through solid rock. Hot-water convection systems are divided into three categories based on reservoir temperatures (White and Williams, 1975): a) high-temperature systems (>150°C); b) intermediate-temperature systems (90° to 150°C); and c) low-temperature systems (<90°C).

Next to each thermal-spring site on the map is a simple diagram showing the temperature of the hottest spring, the estimated convective heat discharged at the surface by spring flow, the total dissolved solids contained in waters from the principal spring, and the estimated reservoir temperature based on chemical geothermometry. A dash indicates no data available for that entry.

Chemical geothermometers are based on temperature-sensitive chemical reactions in hydrothermal fluids and are commonly used to estimate subsurface temperatures at sites where data from drilling are not available. These reactions may control either the absolute amount of an element (for example, silica), relative concentrations of elements (for example, cations), or fractionation of isotopes. By comparing the results of reactions under known conditions with results of analyses of hydrothermal fluids, an estimated reservoir temperature can be calculated. The estimated temperatures derived from geothermometry calculations may represent actual subsurface temperatures if several assumptions about the nature of an individual hydrothermal system are satisfied. For a review of chemical and isotope geothermometers, see Fournier (1981).

GEOLOGY

Geologists now believe that southeastern Alaska is composed of a complex mosaic of fault-bounded tectonostratigraphic terranes. The terranes consist of northwest-trending belts of sedimentary and metamorphic rocks with numerous igneous intrusions. Permian time marks the beginning of a long, complex history of amalgamation and accretion of the terranes to the continental margin of North America. The major episode of accretion occurred in Late Cretaceous time (Berg and others, 1978). Subsequent tectonic activity in Cretaceous and Tertiary times redistributed the terranes along major fault zones. Cenozoic activity also includes intrusion of granitic plutons, thermal metamorphism, and local deposition of continental volcanic and sedimentary rocks. Quaternary volcanism produced the Edgecumbe volcanic rocks north of Sitka and isolated volcanic vents on the south end of Revillagigedo Island and in the eastern Bradfield Canal Quadrangle (Elliott and others, 1981).

The Edgecumbe volcanic field is dominanted by Mt. Edgecumbe, a nearly undissected Holocene stratovolcano that is capped by a caldera 1.6 km in diameter and 240 m deep (Loney and others, 1975); the volcanic field covers 260 km^2 and has a minimum estimated volume of 31 km^3 (Loney and others, 1975; Kosco, 1981). Kosco (1981) has presented evidence that suggests that the Edgecumbe volcanic rocks record two distinct episodes of magmatism, one having tholeiitic characteristics and the other calc-alkaline affinities.

THERMAL SPRINGS

Most thermal springs occur in remote areas, commonly near tidewater or along major rivers. Six sites are located on Chichagof Island, three on Baranof Island and, including Fowler springs in British Columbia, Canada, five within the Stikine River drainage. Two sites are off Behm Canal—one on Bell Island and one near Bailey Bay. Springs also occur on Baker Island and near the head of Bradfield Canal. The recent discovery of the Nylen and Bradfield sites during timber evaluation and logging operations suggests the presence of other hot springs in remote, inaccessible areas. Although no fumaroles or hot springs occur at the Mt. Edgecumbe volcanic field, the overlying permeable volcanic flows could easily mask a hydrothermal system.

Measured thermal-spring temperatures ranged from 21°C (Twin Lake) to 91.5°C (Bailey Bay); spring discharge ranged from 6 lpm (North Peril Strait) to 435 lpm (Chief Shakes). Most thermal springs had low to moderate concentrations of dissolved solids. All springs occur within or near granitic plutons and are distant from any areas of recent volcanism.

The springs probably originated as meteoric waters that circulated along deep fracture systems, which were produced by intense tectonic forces associated with the major fault systems that transect southeastern Alaska. Waters that circulate through the deep fractures are heated by thermal conduction from the surrounding rock; heat is supplied by the regional geothermal flux. Net enthalpy per kilogram of discharge from each spring area was calculated as the difference between the discharge temperature and an assumed average annual temperature of 7°C at the land surface. The total heat discharged at the surface by thermal springs in southeastern Alaska was estimated at 5.5 MW.

RESOURCE BASE

Subsurface temperatures at thermal-spring areas were estimated by using applicable silica and cation geothermometers when available. Mean reservoir temperatures were based on appropriate geothermometers as discussed in Motyka and others (1980) and Brooks and others (1979). No southeastern site had an estimated reservoir temperature >150°C; 10 sites were classified as intermediate-temperature systems (90° to 150°C) and six sites as low-temperature systems (<90°C). Most southeastern sites had estimated subsurface temperatures <115°C. The hottest systems occurred at Goddard, Bailey Bay, and Bell Island.

The total accessible resource base for known hydrothermal systems in southeastern Alaska was estimated at 1.2 x 10^{19}J of energy. This estimate was based on a standard reservoir volume for unexplored systems of 3.4 km as defined by Mariner and others (1978) and on heat energy contained in the reservoir referenced to 15°C as defined by Brooks and others (1979). A much greater geothermal resource base may reside beneath the Edgecumbe volcanic field. On the basis of volcanic-vent distribution and the assumption of a shallow magma chamber, Smith and others (1978) estimated 60 x 10^{19}J of residual heat energy contained in the cooling igneous system beneath Mt. Edgecumbe. Apart from hot-spring areas and regions of recent volcanism, the total geothermal resource base in southeastern Alaska cannot now be estimated because of insufficient thermal-gradient data and conductive heat-flow measurements.

PRESENT USE

Most thermal-spring sites in southeastern Alaska have had little or no development because of their remoteness from major population centers. Several hot-spring areas, however, have been used as recreational sites. The U.S. Forest Service maintains public cabins near White Sulphur Springs and Chief Shakes hot springs and plans to build a cabin and trail to Dalton hot springs. The Sitka Borough constructed bathhouses and walkways at historic Goddard Hot Springs. During the early part of this century, a hotel and 40-room sanitarium were heated by Goddard thermal-spring waters. Tenakee village uses one of its thermal springs to heat a community bathhouse, and at least one local homeowner uses thermal-spring water for space heating. During a pilot geothermal-drilling program sponsored by the Alaska Division of Energy and Power Development, a shallow warm-water aquifer was delineated near Tenakee village at a depth of 50 m; however, the flow rate (~2 lpm) and temperature (~38° C) are not high enough for space heating. Several of the Baranof Hot Springs are leased for a commercial bathhouse and for heating a general store and several local cabins. Bell Island Hot Springs has had the most development. The thermal-spring waters are collected in cisterns and used to heat the main lodge, a large swimming pool, and 14 buildings and cabins at the Bell Island fishing resort. Signs of earlier development at Bailey Bay and Fish Bay hot springs have nearly vanished. Other thermal-spring sites in the Alaska panhandle show little sign of use.

FUTURE USE

Most of the more remote thermal-spring sites in southeastern Alaska are likely to remain in a natural state. Three sites have been nominated for inclusion as ecological preserves by the U.S. Forest Service (Tenakee Inlet, Neka Bay, and Bailey Bay). Thermal-spring sites closer to population centers, however, could be used for a variety of small-scale direct-heating applications (space heating, greenhouses, possible wood and fish processing). Thermal springs with low concentrations of dissolved solids (Fish Bay and Baranof) have a potential for aquaculture. The Sitka Borough has expressed interest in developing the Goddard Hot Springs, and the owner of the Bell Island resort is examining cascaded uses of Bell Island Hot Springs. Reservoir temperatures for southeastern Alaska hot springs are too low to be practical for generation of electricity. The only site with potential for large-scale power development is the Edgecumbe volcanic field north of Sitka. Extensive geological and geophysical exploration are needed, however, to confirm the existence of a developable high-temperature resource.

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ACKNOWLEDGMENTS

We wish to acknowledge Gabriele LaRoche and Shirley Liss (DGGS) for their help in preparing the map and Rocky Reifenstuhl and John Reeder (DGGS) for their assistance in the field. We also wish to acknowledge Robert Mariner (U.S. Geological Survey), Duncan Foley (University of Utah Research Institute), and Donald Turner (Geophysical Institute, University of Alaska, Fairbanks) for their technical review of the map. This work was performed in cooperation with the U.S. Department of Energy (Grant DE-FC07-79ET-27034).

Base modified from Arctic Environmental Information and Data Center, Southeast Alaska, 1981. Universal Transverse Mercator projection on 6° bands, joined at 132° and 138° W. long.

Cartography by G.M. Laird and T.A. Imm.

Table 1. *Quaternary volcanism, southeastern Alaska.*[a]

Map no.	Name	Latitude	Longitude	Elevation	Type of volcano	Eruptions since 1760	Latest activity Date	Latest activity Type	Age of sample	Type of sample	Petrology	Remaining thermal energy
V1	Mt. Edgecumbe	57°03'07" N.	135°45'32" W.	976 m	Stratovolcano	0	8750 B.P.	Explosive	?	Cinder	Basaltic	60x10^{19}J

[a]Data from Smith and others (1978) and Simkin and others (1981).

Table 2. *Water chemistry, geothermometry, and isotopic analysis of thermal springs in southeastern Alaska.*

Site	Date sampled	Water chemistry[a] (mg/l)																			
		T(°C)[f]	pH[f]	SiO_2	Fe	Ca	Mg	Na	K	Li	Sr	HCO_3[f]	SO_4	Cl	F	Br	I	B	H_2S[f]	TDS[g]	SC[h]
Twin Lakes	09/21/79	21	7.0	26	0.03	5.4	0.3	26	1.3	<0.01	--	30	32	60	0.3	0.1	--	0.1	--	112	150
Mount Rynda	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chief Shakes	09/18/79	51	7.9	70	<0.01	14	0.1	85	3.0	0.01	--	49	140	4.9	1.3	0.3	--	<0.01	--	338	430
Barnes Lake	09/25/79	26	7.0	71	0.17	8.9	0.4	72	3.5	0.02	--	--	110	13	2.3	--	--	0.05	--	249	460
Fowler	09/24/79	60	8.0	66	0.03	52	0.3	200	9.8	0.10	--	29	230	250	1.6	1	--	0.1	--	830	1,250
Bradfield Canal	10/02/79	57	8.2	87	0.02	13	<0.1	120	5.7	0.04	--	42	240	30	2.5	0.2	--	0.1	--	512	890
Bailey Bay	10/12/79	92	8.9	140	<0.01	1.3	<0.1	100	4.4	0.06	--	129	39	49	3.1	<0.1	--	0.6	--	407	480
Bell Island	10/05/79	74	8.5	110	<0.01	8.3	<0.1	180	7.2	0.15	--	58	120	200	4.6	0.1	--	0.6	--	650	950
Dalton	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Goddard	05/30/81	66	7.1	110	0.19	353	1.6	1,300	66	1.6	3.5	30	90	2800	1.7	10	0.4	1.0	2.5	4,740	8,500
Baranof	05/22/81	50	8.6	67	<0.01	1.7	<0.1	58	1.1	0.06	<0.1	99	44	9.2	1.1	--	--	<0.01	9.5	280	275
Fish Bay	05/28/81	46	8.7	75	<0.01	1.2	<0.1	82	2.3	0.10	<0.1	93	93	9.8	2.5	--	--	7.8	12	275	330
Nylen	05/27/81	51	8.5	42	0.01	110	<0.1	170	2.1	0.03	0.7	14	590	13	0.8	--	--	2.1	0.2	952	1,250
Tenakee	05/17/81	41	9.1	51	0.02	24	<0.1	210	3.1	0.10	0.7	57	300	100	5.0	--	--	4.9	3.1	743	1,100
North Peril Strait	05/27/81	41	8.7	30	0.02	36	1.2	140	2.1	0.01	0.3	26	330	19	1.2	--	--	3.8	0.3	585	900
White Sulfur Springs (Hoonah)	06/06/81	44	8.3	32	<0.01	4.8	<0.1	43	0.7	0.03	<0.1	44	30	30	1.2	--	--	<0.1	--	185	250
Tenakee Inlet	05/20/81	80	8.2	85	<0.01	8.4	<0.1	140	3.1	0.03	0.1	62	220	29	1.1	--	--	5.0	0.8	543	700
Neka Bay	05/16/81	47	8.1	51	0.03	36	<0.1	150	2.5	0.03	0.5	42	340	15	1.0	--	--	3.0	1.3	635	950

Site	Geothermometry[b] (°C)			Isotope analysis[c] (per mil; relative to SMOW[d])			
	Quartz[i]	Chalcedony	Na-K-Ca	Thermal spring $\delta^{18}O$	Thermal spring D[j]	LDMW[e] $\delta^{18}O$	LDMW[e] D
Twin Lakes	73	41	49	-12.4	-92		
Mount Rynda	--						
Chief Shakes	118	90	66	-14.1	-109		
Barnes Lake	118	90	62	-14.5	-108		
Fowler	115	86	85	-13.1	-124		
Bradfield Canal	130	102	142	-14.4	-109		
Bailey Bay	140	106	153	-13.0	-98		
Bell Island	136	108	144	-13.7	-110		
Dalton	--						
Goddard	141	115	155	-12.4	-87	-10.8	-74
Baranof	114	81	77	-14.0	-98	-12.1	-85
Fish Bay	115	86	130	-12.7	-97	-11.6	-77
Nylen	96	63	37	-13.9	-97	-12.9	-87
Tenakee	91	60	65	-13.8	-100	-12.7	-91
North Peril Strait	83	48	42	-13.0	-90	-12.4	-81
White Sulfur Springs (Hoonah)	85	51	38	-11.3	-78	(-10.8)[k]	(-74)[k]
Tenakee Inlet	126	101	114	-14.1	-97	(-14.9)[k]	(-100)[k]
Neka Bay	103	73	47	-14.9	-100	--	--

[a]Chemical analyses by M.A. Moorman, DGGS.
[b]Geothermometry based on empirical relationships in Fournier (1981).
[c]Isotope analysis by R.S. Harmon, Southern Methodist University.
[d]SMOW = Standard mean ocean water.
[e]LDMW = Locally derived meteoric waters. Samples normally obtained at same elevation as thermal-spring sites; values averaged when more than one analysis available.
[f]Field measurement by R.J. Motyka and M.A. Moorman, DGGS.
[g]TDS = Total dissolved solids. Computed value.
[h]SC = Specific conductance (microsiemens/cm at 25°C).
[i]Based on pH-corrected, empirical relationship for no-conductive cooling.
[j]Deuterium (heavy isotope of hydrogen).
[k]LDMW data not available for specified location; value in parentheses is from closest site with available data.
-- No data.

GEOTHERMAL RESOURCES OF SOUTHEASTERN ALASKA

By

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1987

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