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Lithium Resources and Production: a critical global assessment

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LITHIUM RESOURCES AND PRODUCTION:

A CRITICAL GLOBAL ASSESSMENT

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Contents

CHAPTER 1

Introduction

This report examines the available data on lithium resources and historical production, providing a basis to understand the future of a rapidly emerging critical metal to meet sustainability needs such as lithium ion batteries for electric cars. Its aim in assembling available data, is to provide a foundation - for our research team and for others - to explore future questions related to teh energy intensity of lithium extraction and processing; the role of Australia's lithium and how it can be utilised to derive long term benefit.

This work is part of the Mineral Futures Research Cluster within the Mineral Future Initiative of the CSIRO Minerals Down Under Flagship comprising the University of Queensland (Centre for Social Responsibility in Mining at the Sustainable Minerals Institute); University of Technology, Sydney (Institute for Sustainable Futures with input from Dr. Gavin Mudd, Dr. Steve Mohr, Monash University); Curtin University of Technology; CQ University; Australian National University and CSIRO.

Specifically it is part of the P1 cluster project which includes developing a research database from which the impacts of peak minerals can be monitored and evaluated. This, together with research on strategic foresight forms the 'Commodity Futures' program of work. Research by other university partners is being undertaken concurrently on 'Technology Futures' (P2) and 'Regions in Transition' (P3).

The report structure is as follows: the uses of lithium are outlined in Section 1.1; Section 1.2 describes the current methods of extracting lithium. Statistics such as historic lithium production, lithium reserves and resource information will be presented in Section 1.3. Section 1.4 presents conclusions and outlines further research directions.

1.1. Uses of Lithium

Lithium is used for a variety of processes, including light weight lithium batteries, in ceramics and glass to reduce the melting point and increase the shatter resistance. Lithium is also used in some greases, the production of aluminium and as drug to control bipolar and other mental illnesses.

Demand for lithium batteries is expected to grow rapidly as electric cars accelerate into the transport vehicle mix. Given the size of potential demand by electric cars, concerns have been raised (Tahil, 2007, 2008) as to whether there is sufficient lithium available to meet this demand.

This report analyses this issue in depth, by compiling a comprehensive statistical data set on lithium resources and production, providing a sound basis to examine future global production scenarios for lithium.

1.2. Production methods

Lithium is currently produced from two different sources. The first is from hardrock ore deposits, which are most commonly based on spodumene minerals. The second is from brines, commonly salt lakes (or 'Salars') with high lithium concentrations. Lithium from ores is typically concentrated to around 5% lithium and used directly in the manufacturing of glass and ceramics, although it is also possible to produce lithium carbonate. Lithium typically in the form of lithium carbonate is extracted from brines by using evaporative ponds, although lithium chloride and/or lithium hydroxide is sometimes produced. Before 1980 the production of lithium was mostly via ore deposits, however since 1980 brine production has been favoured due to lower production costs (for lithium carbonate). This has seen serveral mines in the US and Canada close due to being uneconomic compared to brine operators.

1.3. Statistics

The statistics on lithium are shown in Tables 1.1 – 1.8, and Figures 1.1 and 1.2. In particular, the reserves of lithium by deposit for various literature sources is shown in Table 1.1 and reserves by type is shown in Table 1.2. Table 1.3 has the resources of lithium found in the literature. The lithium resources in Table 1.3 include lithium reserve numbers, the resource estimates refer to lithium in place[1] whereas the reserve estimates refer to the extractable portion of the resources. Table 1.4 has the production of lithium by country[2] and Figure 1.2 shows this production. Figure 1.1 shows the lithium production by type, although considerable uncertainty exists primarily due to insufficient statistics from the USA and China. Information by basin for brine deposits is shown in Table 1.6 (the sources for the information are found in the Appendices). Likewise, information by basin for ore deposits is shown in Table 1.8.

Table 1.1: Lithium reserves by Country (Mt Li)

Country	Deposit	Type	Tahil[a]	USGS[b]	Clarke[c]	Yaksic[d]	This report
Argentina	Hombre Muerto	Brine	0.4	0.8[e]	6[e]	0.367	0.4
Argentina	Rincon	Brine	0.25			0.842	1.40
Argentina	Olaroz	Brine	0.16			0.146	0.14
Argentina	Cauchari	Brine					0.463
Australia	Greenbushes	Ore		0.58[f]	1.603[f]	0.128	0.223
Australia	Mt Marion	Ore				0.01	0.0298
Australia	Mt Cattlin	Ore	0.0282			0.032	0.056
Austria	Koralpe	Ore			0.113	0.05	0.01
Bolivia	Uyuni	Brine	0.6		5.4	2.475	3.56
Brazil	Country	Ore		0.19	0.123	0.085	0.043

[1]however for the case of Evans (2008a) resources for some deposits have been reduced to account for mining losses

[2]These production statistics have been compiled from data in U.S. Bureau of Mines (var); Mineral Commodity Summary (var); Kelly and Matos (2009); Crowson (Var); Minerals UK (var); ABS (1961); Rothwell (var); Garrett (2004); Anstett et al. (1990); NSW Legislative Assembly (var); Government of WA (var, 2010)

Table 1.1: (continued)

Country	Deposit	Type	Tahil[a]	USGS[b]	Clarke[c]	Yaksic[d]	This report
Canada	Bernic Lake	Ore		0.18[g]	1.073[g]	0.009	0.019
Canada	Wekusko	Ore				0.013[h]	0.054
Canada	La Corne	Ore				0.053	0.163
Canada	La Motte	Ore				0.011	0.023
Canada	Sep. Rapids	Ore				0.036	0.056
Canada	Yellowknife					0.065	
Canada	Fox Creek	Oil[i]					0.258
Chile	Atacama	Brine	1	7.5[j]	7.52[j]	16.065	7.5
Chile	Maricunga	Brine				0.099	0.22
China	Zhabuye	Brine	0.75	0.54[k]	6.173[k]	0.689	0.752
China	Qinghai[l]	Brine	0.5			0.909	1
China	DXC	Brine	0.08			0.063	0.141
China	Jaijika	Ore				0.225	0.24
China	Gajika	Ore				0.28	0.3
China	Maerkang	Ore				0.11	0.225
China	Yichun	Ore					0.16
China	Daoxin	Ore					0.09
Finland	Country	Ore			0.013	0.0064	0.015
FSU	Country	Ore			2.48	0.58	0.13
Ireland	Country	Ore			0.013		
Israel	Dead Sea	Brine				0.9	
Mali	Country	Ore				0.013	0.004
Namibia	Country	Ore				0.006	0.01
Portugal	Country	Ore			0.01	0.005	0.01
Serbia	Country	Jad.[m]			0.957	0.45	0.425
South Africa	Country	Ore					0.015
Spain	Country	Ore			0.072		
USA	Silver Peak	Brine	0.118	0.038[n]	6.62[n]	0.018	0.02
USA	Searles Lake	Brine				0.014	0
USA	Great Salt	Brine				0.237	0.26
USA	Salton Sea	Brine				0.45	0.316
USA	North Carolina[o]	Ore				0.238	0.23
USA	North Carolina[p]	Ore				1.3	1
USA	Smackover	Oil[i]				0.45	0.5
USA	McDermitt	Hect.[q]				1[r]	1
Zaire	Manono	Ore			1.145	1.15	1.5
Zimbabwe	Bikita	Ore		0.023	0.057	0.028	0.023
Total			3.886	9.851	39.372	29.584	23.044

Table 1.1: (continued)

Country	Deposit	Type	Tahil[a]	USGS[b]	Clarke[c]	Yaksic[d]	This report

[a]Tahil (2008)
[b]Mineral Commodity Summary (var)
[c]Clarke and Harben (2009) Broad based reserves
[d]Yaksic and Tilton (2009) recoverable resources
[e]All of Argentina
[f]All of Australia
[g]All of Canada
[h]Thompson Brother
[i]Oil field brine
[j]All of Chile
[k]All of China
[l]Including Taijinaier
[m]Jadarite
[n]all of USA
[o]Developed
[p]Undeveloped
[q]Hectorite
[r]All Hectorite

TABLE 1.2. The lithium reserves by type (Mt Li)

Type	Tahil (2008)	Yaksic and Tilton (2009)	This Study
Brine	3.9	23.4	16.6
Ore	4.0	4.4	4.2
Oil field brines		0.5	0.8
Hectorite		1.0	1.1
Jadarite		0.5	0.4
Total	7.9	29.6	23.0

Table 1.3: Lithium resources by Country (Mt Li)

Country	Deposit	Type	Evans[a]	Tahil[b]	USGS[c]	Yaksic[d]	Gruber[e]	This study
Argentina	Hombre Muerto	Brine	0.85	0.8	2.5[f]	0.815	0.8	0.8
Argentina	Rincon	Brine	1.40	0.5		1.87	1.118	2.80
Argentina	Olaroz	Brine	0.3	0.32		0.325	0.156	0.28
Argentina	Cauchari	Brine						0.926
Australia	Greenbushes	Ore	0.223			0.255	0.56	0.73
Australia	Mt Marion	Ore	0.0198			0.0198		0.05954
Australia	Mt Cattlin	Ore	0.02			0.0645		0.0797
Austria	Koralpe	Ore	0.1			0.1	0.1	0.077
Bolivia	Uyuni	Brine	5.5	5.5	9[g]	5.5	10.2	8.9
Brazil	Country	Ore	0.085			0.085	0.1	0.91
Canada	Bernic Lake	Ore	0.0186			0.0186		0.073
Canada	Wekusko	Ore	0.028			0.026[h]		0.072

Table 1.3: (continued)

Country	Deposit	Type	Evans[a]	Tahil[b]	USGS[c]	Yaksic[d]	Gruber[e]	This Study
Canada	La Corne	Ore	0.09			0.106		0.3661
Canada	La Motte	Ore	0.023			0.0226		0.035
Canada	Sep. Rapids	Ore	0.056			0.0722		0.076
Canada	Yellowknife		0.04			0.129[i]		
Canada	Fox Creek	Oil[j]					0.515	0.515
Chile	Atacama	Brine	6.9	3	7.5[k]	35.7	6.3	15
Chile	Maricunga	Brine				0.22	0.22	0.44
China	Zhabuye	Brine	2.6[l]	1.25	2.5[m]	1.53	1.53	1.53
China	Qinghai[n]	Brine		1		2.28	2.02	2.3
China	DXC	Brine		0.16		0.1406	0.181	0.17
China	Jaijika	Ore	0.75[o]			0.45	0.204	0.48
China	Gajika	Ore				0.56	0.591	0.59
China	Maerkang	Ore				0.22	0.225	0.45
China	Yichun	Ore					0.325	0.325
China	Daoxin	Ore					0.182	0.181
Finland	Country	Ore	0.014			0.0128		0.03
FSU	Country	Ore	1			1.16	0.844	1.16
Israel	Dead Sea	Brine		2		2		
Mali	Country	Ore				0.026		0.026
Namibia	Country	Ore				0.0115		0.0115
Portugal	Country	Ore				0.01		0.02
Serbia	Country	Jad.[p]	0.85			0.9	0.99	0.85
South Africa	Country	Ore						0.03
USA	Silver Peak	Brine	0.04	0.3	2.5[q]	0.04	0.3	0.04
USA	Searles Lake	Brine		0.02		0.0316		0.0316
USA	Great Salt	Brine		0.53		0.526		0.5
USA	Salton Sea	Brine	1	1		1	1.316[r]	1
USA	North Carolina[s]	Ore	0.23			0.535	5.454[t]	
USA	North Carolina[u]	Ore	2.6			2.6		2.6
USA	Smackover	Oil[j]	0.75	1		1	0.75	1
USA	McDermitt	Hect.[v]	2			2	2	2
Zaire	Manono	Ore	2.3			2.3	1.145	3.1
Zimbabwe	Bikita	Ore	0.0567			0.0567	0.0567	0.0567
Other							0.147	
Total			29.8	17.4	25.5	64.0	38.3	50.2

[a]Evans (2008a)
[b]Tahil (2008)
[c]Mineral Commodity Summary (var)
[d]Yaksic and Tilton (2009)
[e]Gruber and Medina (2010)
[f]All of Argentina
[g]All of Bolivia
[h]Thompson Brother
[i]Other Canada
[j]Oil field brine
[k]All of Chile

[l]All Chinese brine
[m]All of China
[n]Including Taijinaier
[o]All Chinese Ore
[p]Jadarite
[q]all of USA
[r]Salton Sea and Brawley
[s]Developed
[t]North Carolina
[u]Undeveloped
[v]Hectorite

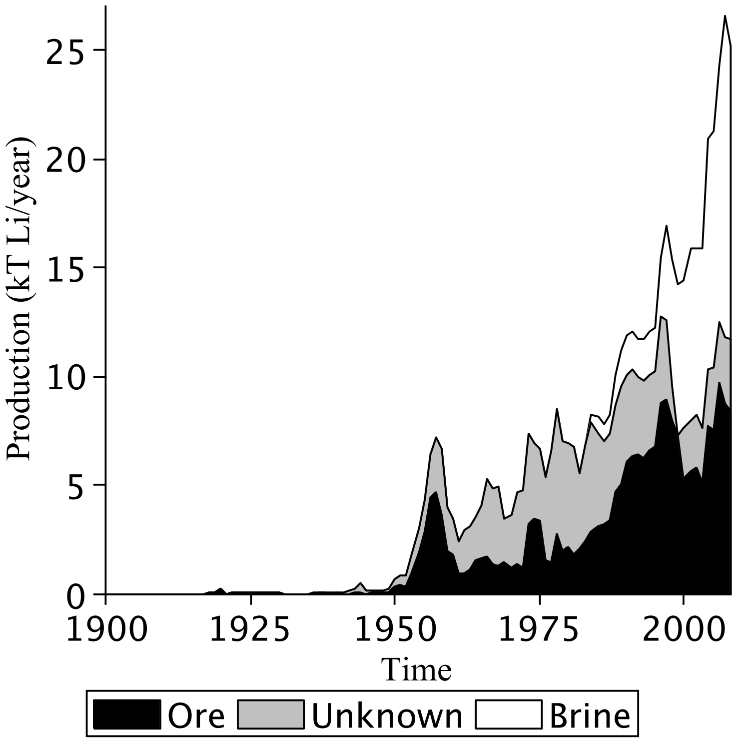

FIGURE 1.1. Annual production of lithium by source

Table 1.4: Historical production statistics by source (t Li)

Year	Arg.[a]		Aus.[b]	Can.[c]	Chile	China	FSU	Por.[d]	USA	Zim.[e]	Rest	Total			
	O[f]	B[g]	O[f]	O[f]	B[g]	U[h]	O[f]	O[f]	U[h]	O[f]	O[f]	O[f]	B[g]	U[h]	A[i]
1899									40[f]			40	0	0	40
1900									10[f]			10	0	0	10
1901									35[f]			35	0	0	35
1902									25[f]			25	0	0	25
1903									23[f]			23	0	0	23
1904			1[j]						12[f]			13	0	0	13
1905									2[f]			2	0	0	2
1906									8[f]			8	0	0	8
1907									11[f]			11	0	0	11
1908									4[f]			4	0	0	4
1909									4[f]			4	0	0	4
1910			0						5[f]			5	0	0	5
1911									10[f]			10	0	0	10
1912									7[f]			7	0	0	7
1913									11[f]			11	0	0	11

Table 1.4: (continued)

Year	Arg.[a]		Aus.[b]	Can.[c]	Chile	China	FSU	Por.[d]	USA	Zim.[e]	Rest	Total			
	O[f]	B[g]	O[f]	O[f]	B[g]	U[h]	O[f]	O[f]	U[h]	O[f]	O[f]	O[f]	B[g]	U[h]	A[i]
1914									11[f]			11	0	0	11
1915									10[f]			10	0	0	10
1916									12[f]			12	0	0	12
1917									41[f]			41	0	0	41
1918									118[f]			118	0	0	118
1919									126[f]			126	0	0	126
1920									234[f]			234	0	0	234
1921									37[f]			37	0	0	37
1922									44[f]			44	0	0	44
1923									46[f]			46	0	0	46
1924			0[j]						60[f]			60	0	0	60
1925			2[j]					8[j]	63[f]		11	84	0	0	84
1926								5[j]	74[f]		17	97	0	0	97
1927				1[j]				12[j]	84[f]	0[j]	17	114	0	0	114
1928				1[j]				13[j]	92[f]		20	125	0	0	125
1929				2[j]				15[j]			37	54	0	0	54
1930				2[j]				6[j]	36[f]		24	67	0	0	67
1931								12[j]			3	15	0	0	15
1932								12[j]			3	15	0	0	15
1933								7[j]	10[f]			17	0	0	17
1934			0					6[j]	14[f]		7	28	0	0	28
1935									23[f]		15	38	0	0	38
1936	1[j]							0[j]	25		26	27	0	25	52
1937	4[j]			1[j]				2[j]	27		44	51	0	27	78
1938	3[j]								22		46	49	0	22	72
1939									50		38	38	0	50	87
1940									53		44	44	0	53	97
1941	1[j]							1[j]	97		20	22	0	97	119
1942									139		29	29	0	139	168
1943	2[j]		0					4[j]	215		60	65	0	215	280
1944								4[j]	394		87	91	0	394	485
1945								0[j]	127		35	35	0	127	162
1946	0[j]								150		53	53	0	150	203
1947									93		94	94	0	93	187
1948									135	7[j]	48	54	0	135	189
1949			0[j]					1	221		48	49	0	221	270
1950								1	347	6	310	316	0	347	663
1951	0[j]							2	444	79	361	442	0	444	886
1952								0	505	44	310	355	0	505	860
1953								1	821	589	396	986	0	821	1807
1954	1[j]		0[j]	4				0	1140	1622	296	1924	0	1140	3064
1955	2[j]		0[j]	24				0	1500[j]	2465	369	2860	0	1500	4360
1956	3[j]			1010					2000[j]	3096	293	4402	0	2000	6402
1957	0[j]			1084					2500[j]	3278	307	4670	0	2500	7170
1958	3[j]		1[j]	813					3000	2560	274	3652	0	3000	6652
1959	3[j]		0[j]	581					2000[j]	1051[j]	322	1957	0	2000	3957
1960	3[j]		0[j]	43					1600	1492	295	1833	0	1600	3433
1961	8[j]		2[j]	113					1500	670	167	960	0	1500	2460
1962	9[j]		3[j]	105					2000[j]	710	118	945	0	2000	2945
1963	29[j]		7[j]	136					2000[j]	898[j]	91	1160	0	2000	3160
1964	14[j]		4[j]	223					2000[j]	1219[j]	62	1522	0	2000	3522
1965	12[j]		4[j]	214					2500	1155[j]	223	1609	0	2500	4109
1966	17		14[j]	53					3500[j]	1590	80	1755	0	3500	5255
1967	7		9[j]	92					3500[j]	1200[j]	59	1367	0	3500	4867
1968	3[j]		10[j]						3700	1216[j]	62	1291	0	3700	4991
1969	7[j]		10[j]	84				0[j]	2000	1216[j]	197	1514	0	2000	3514
1970	5		11[j]	197				9	2440	862	146	1230	0	2440	3670
1971	5		23[j]	100[j]				18	3357	862	346	1354	0	3357	4710
1972	5		15[j]	100[j]				23	3538	862	227	1232	0	3538	4770
1973	9		3[j]	86		181[j f]	1633	36	4209	862	364	3175	0	4209	7384

Table 1.4: (continued)

Year	Arg.[a]		Aus.[b]	Can.[c]	Chile	China	FSU	Por.[d]	USA	Zim.[e]	Rest	Total			
	O[f]	B[g]	O[f]	O[f]	B[g]	U[h]	O[f]	O[f]	U[h]	O[f]	O[f]	O[f]	B[g]	U[h]	A[i]
1974	9		0[j]	332		180[j][f]	1633	36	3500	862	409	3461	0	3500	6961
1975	9			91		180[j][f]	1814	9	3301	862	420	3385	0	3301	6686
1976	13[j]			29		180[j][f]	907[j]	24[j]	3834	181[j]	188	1522	0	3834	5356
1977	8[j]					200[j][f]	998[j]	24[j]	5114	161[j]	96	1487	0	5114	6601
1978	18					270[f]	1300	24[j]	5711	900	298	2810	0	5711	8521
1979	10					300[f]	1300	6	5000	264[j]	111	1991	0	5000	6991
1980	2					390[f]	1250	7	4792	405	107	2161	0	4792	6953
1981	1		1			390[f]	1250	6	4922	111	80	1839	0	4922	6761
1982	3		3			420[f]	1350	6	3468	194	75	2051	0	3468	5519
1983	4		81			555[f]	1350	4	4450	357	57	2408	0	4450	6858
1984	1		217	3	396	835[f]	1350	7	4992	425	35	2873	396	4992	8261
1985	1		363	10	847	835[f]	1350	1	4200	530	56	3146	847	4200	8193
1986	1		357	16	837	835[f]	1350	36[j]	3805	534	56	3185	837	3805	7827
1987	1		360	140	910	455[f]	1640	14	4000	680	71	3361	910	4000	8271
1988	2		900	420	1390	260[f]	2200	310	4000	510	49	4651	1390	4000	10041
1989	2		1200	440	1700	300[f]	2200	400	4500	410	81	5033	1700	4500	11233
1990	1		1300	440	1800	2630[f]	1100	150	4000	410	77	6108	1800	4000	11908
1991	6		1600	380	1700	2710[f]	1000	200	4000	380	54	6330	1700	4000	12030
1992	12		1500	590	1800	2710[f]	1000	180	3500	400	56	6448	1800	3500	11748
1993	6		1600[j]	590	1900[j]	2710[f]	800	180	3500	360	46	6292	1900	3500	11692
1994	8		1700	630	2000	2800[f]	800	180	3500	380	72	6570	2000	3500	12070
1995	8		1700	660	2000	2800[f]	800	180	3500	520	84	6752	2000	3500	12252
1996	8		3700	690	2700	2800[f]	800	160	4016	500	80	8738	2700	4016	15454
1997	8	244[j]	1457	1600	4100	2900[f]	2000	180	3705	700	72	8917	4344	3705	16966
1998		1130	1106	700	4700	3000[f]	2000	160	1550	1000	60	8026	5830	1550	15406
1999		200	1392	710	5300	2300[f]	2000	140	1490[g]	700	32	7274	6990	0	14264
2000		200	1660	710	5300	2400	2000	140	1230[g]	740	30	5280	6730	2400	14410
2001		200	1803	700	6800	2400	2000	200	890[g]	700	220	5623	7890	2400	15913
2002		946	2000	707	5920	2400	2000	190	800[g]	640	319	5856	7666	2400	15922
2003		960	3408	710	6580	2500		190	720[g]	480	328	5117	8260	2500	15877
2004		1970	3930	707	7990	2630	2200	320	680[g]	240	287	7684	10640	2630	20954
2005		1980	3770	707	8270	2820	2200	320	640[g]	260	336	7593	10890	2820	21303
2006		2900	5500	707	8200	2820	2200	320	740[g]	600	358	9685	11840	2820	24345
2007		3000	6910	707	11100	3010		570	700[g]	300	306	8793	14800	3010	26603
2008		2200	6280	690	10600	3290		700	590[g]	500	286	8456	13390	3290	25136

[a]Argentina
[b]Australia
[c]Canada
[d]Portugal
[e]Zimbabwe
[f]Ore
[g]Brine
[h]Unknown
[i]All sources
[j]Estimated

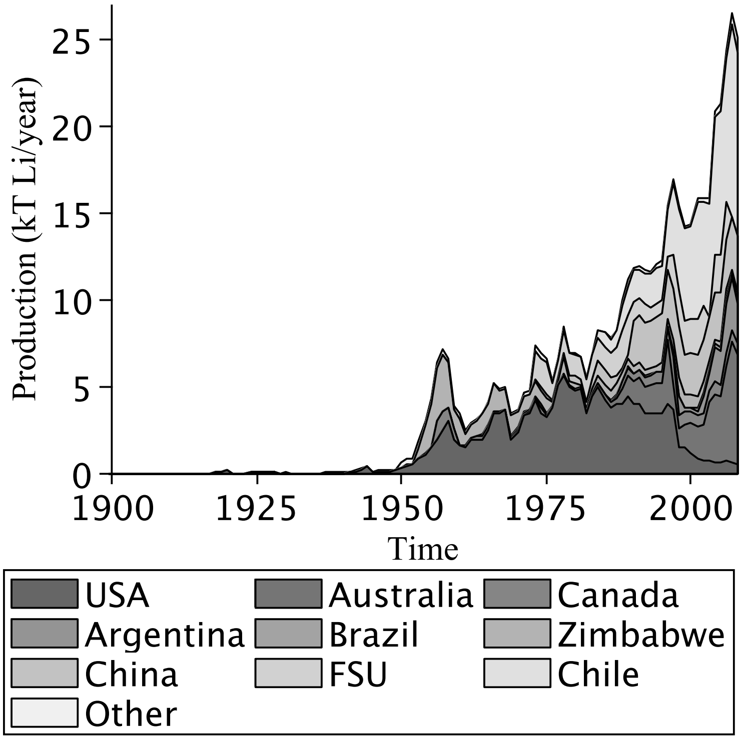

FIGURE 1.2. Annual production of lithium by country

Table 1.5: Historical production statistics by source (t ore)

Year	Arg.[a]		Aus.[b]	Can.[c]	Chile	China	FSU	Por.[d]	USA	Zim.[e]	Rest	Total			
	O[f]	B[g]	O[f]	O[f]	B[g]	U[h]	O[f]	O[f]	U[h]	O[f]	O[f]	O[f]	B[g]	U[h]	A[i]
1899									?		0	?	0	0	?
1900									?		0	?	0	0	?
1901									?		0	?	0	0	?
1902									1129[f]		0	1129	0	0	1129
1903									1012[f]		0	1012	0	0	1012
1904									523[f]		0	523	0	0	523
1905			20						72[f]		0	92	0	0	92
1906									347[f]		0	347	0	0	347
1907									481[f]		0	481	0	0	481
1908									184[f]		0	184	0	0	184
1909									136[f]		0	136	0	0	136
1910			3						?		0	?	0	0	?
1911									?		0	?	0	0	?
1912									?		0	?	0	0	?
1913									?		0	?	0	0	?
1914									?		0	?	0	0	?
1915									?		0	?	0	0	?
1916									?		0	?	0	0	?
1917									?		0	?	0	0	?
1918									5900[f]		0	5900	0	0	5900
1919									5900[f]		0	5900	0	0	5900
1920									10611[f]		0	10611	0	0	10611
1921									?		0	?	0	0	?
1922									?		0	?	0	0	?
1923									?		0	?	0	0	?
1924			5						?		0	?	0	0	?
1925			39					308	2849[f]		533	3730	0	0	3730
1926								229	3357[f]		943	4528	0	0	4528
1927				22				480	3786[f]	19	958	5264	0	0	5264
1928				16				495	4173[f]		1285	5970	0	0	5970
1929				64				760			2313	3137	0	0	3137
1930				59				274	1630[f]		1070	3034	0	0	3034
1931								578			102	680	0	0	680
1932								589			102	691	0	0	691
1933								280	457[f]		0	738	0	0	738
1934			15					299	652[f]		235	1202	0	0	1202
1935									1047[f]		497	1544	0	0	1544
1936	60							8	1126		865	933	0	1126	2059
1937	184			29				110	1231		1723	2046	0	1231	3277
1938	169								809		1535	1704	0	809	2513
1939									1805		1252	1252	0	1805	3057
1940									1824		1612	1612	0	1824	3436
1941	50							20	3476		857	927	0	3476	4403
1942									5811		1179	1179	0	5811	6990
1943	75		8					91	7398		2443	2618	0	7398	10016
1944								100	12083		3393	3493	0	12083	15576
1945								2	2219		1173	1175	0	2219	3394
1946	2								2781		1756	1758	0	2781	4538
1947									2214		3131	3131	0	2214	5346
1948									3521	327	1597	1924	0	3521	5445
1949			5					18	4389		1854	1878	0	4389	6267
1950								16	8442	181	?	?	0	8442	?
1951	1							67	11700	2400	?	?	0	11700	?
1952								10	14162	1342	?	?	0	14162	?
1953								16	24712	17820	?	?	0	24712	?
1954	38		15	?				9	34319	49034	?	?	0	34319	?
1955	100		4	?				4	?	74540	?	?	0	?	?
1956	150			?					?	93634	?	?	0	?	?
1957	20			?					?	99115	?	?	0	?	?
1958	159		69	?					?	77415	?	?	0	?	?
1959	170		25	?					?	52527	8463	?	0	?	?

Table 1.5: (continued)

Year	Arg.[a]		Aus.[b]	Can.[c]	Chile	China	FSU	Por.[d]	USA	Zim.[e]	Rest	Total			
	O[f]	B[g]	O[f]	O[f]	B[g]	U[h]	O[f]	O[f]	U[h]	O[f]	O[f]	O[f]	B[g]	U[h]	A[i]
1960	139		16	?					?	79691	7332	?	0	?	?
1961	402		127	?					?	50114	6257	?	0	?	?
1962	450		138	?					?	41105	5324	?	0	?	?
1963	1441		439	?					?	44888	2419	?	0	?	?
1964	725		264	?					?	60929	1582	?	0	?	?
1965	622		315	?					?	57740	9318	?	0	?	?
1966	270		1009	?					?	60000	?	?	0	?	?
1967	247		678	?					?	60000	?	?	0	?	?
1968	127		750						?	60781	?	63708	0	?	?
1969	352		721	?				?	?	60781	?	?	0	?	?
1970	245		784	?				250	?	60781	10608	?	0	?	?
1971	81		1675	?				750	?	60781	10070	?	0	?	?
1972	49		1071	?				1200	?	13608	?	?	0	?	?
1973	100		222	?		9072[f]	45359	1200	?	13608	9513	?	0	?	?
1974	164		1	?		9000[f]	45359	1200	?	13608	43188	?	0	?	?
1975	250			?		9000[f]	45359	1200	?	9072	57266	?	0	?	?
1976	675			?		9000[f]	45359	1179	?	9072	9572	?	0	?	?
1977	412					10000[f]	49895	1179	?	8050	4785	74322	0	?	?
1978	803					10000[f]	49895	1179	?	16688	5893	84458	0	?	?
1979	106					10000[f]	49895	998	?	13197	4274	78470	0	?	?
1980	80					13600[f]	54975	998	?	19942	5848	95443	0	?	?
1981	25					14000[f]	54975	898	?	16444	3865	90207	0	?	?
1982	113		80			14000[f]	54975	905	?	9787	3814	83675	0	?	?
1983	152		2492			15000[f]	54975	545	?	19193	2902	95261	0	?	?
1984	25		6668	1270	2110	15000[f]	54975	30	?	22548	1727	102244	2110	?	?
1985	35		12009	4600	4508	15000[f]	55000	4	?	27910	3447	118005	4508	?	?
1986	184		8530	7500	4458	15000[f]	55000	1800	?	32760	2914	123688	4458	?	?
1987	178		16621	11500	6139	15000[f]	55000	9380	?	14959	4419	127057	6139	?	?
1988	119		27396	14000	7332	15000[f]	55000	14109	?	15073	3113	143810	7332	?	?
1989	84		39105	14000	7508	15000[f]	55000	18264	?	20647	2986	165086	7508	?	?
1990	69		50576	12000	9080	15000[f]	55000	10600	?	19100	1739	164084	9080	?	?
1991	287		43281	12000	8580	15500[f]	50000	10000	?	9190	3154	143412	8580	?	?
1992	620		39980	18500	10823	7220[f]	45000	15904	?	12837	4850	144911	10823	?	?
1993	300		33353	18900	10369	8248[f]	3000	13289	?	18064	6233	101387	10369	?	?
1994	400		61708	20000	10439	9050[f]	2000	11352	?	25279	8759	138548	10439	?	?
1995	400		80135	21000	12943	12800[f]	2000	8740	?	33498	9782	168355	12943	?	?
1996	400		139287	22000	14180	15000[f]	2000	7626	?	30929	8542	225784	14180	?	?
1997	697	1876	56567	22500	24246	15500[f]	?	6883	?	49833	7541	?	26122	?	?
1998		8583	42337	22500	28377	13000[f]	?	7000	?	28055	9542	?	36960	?	?
1999		4387	54023	22500	30231	12500[f]	?	14862	?	36671	11071	?	?	0	?
2000		7343	65504	22500	35869	13000	?	9352	?	37914	10873	?	?	13000	?
2001		4512	79859	22500	31320	13000	?	11571	?	36103	9084	?	?	13000	?
2002		5635	79085	22500	35242	13000	?	16325	?	33172	18846	?	?	13000	?
2003		7550	124410	22500	41667	13500		24606	?	12131	16088	199735	?	13500	?
2004		11273	118451	22500	44465	14000	?	28696	?	13710	12290	?	?	14000	?
2005		15700	173635	22500	44276	15000	?	26185	?	37499	15675	?	?	15000	?
2006		16560	222101	22500	51201	15000	?	28497	?	30000	16924	?	?	15000	?
2007		17000	245279	22500	59637	16000		34755	?	30000	16991	349525	?	16000	?
2008		17800	239528	22000	56880	17500		35000	?	25000	17000[j]	338528	?	17500	?

[a]Argentina
[b]Australia
[c]Canada
[d]Portugal
[e]Zimbabwe
[f]Concentrate ore
[g]Brines, lithium carbonate and chloride
[h]Unknown
[i]All

[j]Spainish production estimated to be 9000

Table 1.6: Brine Basin Information

Country	Deposit	Li grade (wt.%)	Mg:Li (-)	Evap. rate (m/y)	Elv.[a] (km)	surf. area (10^3 km^2)	Por.[b] (%)	depth (m)	ρ^c (g/mL)	Comm.[d]
Arg.[e]	H. Muerto[f]	0.062	1.37	2.6–2.8	3.7–4.3	565	15	15	∼1.2	1997
Arg.[e]	Rincon	∼0.04	8.5–8.6	2.6	3.7	0.25–0.28	23–30	30–40	1.204	2011
Arg.[e]	Olaroz	0.07	2.8	2.6–2.8	?	0.12	6-8[g]	55	1.2	2012
Arg.[e]	Cauchari	0.051	2.84	?	3.95	?	?	?	1.215	NA[h]
Bolivia	Uyuni	0.045	∼ 20	1.5	3.65	∼10	35	11–20	1.211	2014[i]
Chile	Atacama	0.15	6.4	3–3.7	2.3	3	18[j]	200[k]	1.223	1984
Chile	Maricunga	0.092	8	2.6	?	?	?	?	?	NA
China	Zhabuye	∼0.1	0.001	2.3	4.42	0.243	?	0.7	1.297	2005
China	Qinghai[l]	∼0.03	34+	3.56	2.79	?	?	?	?	2004[m]
China	DXC	0.033	0.25	2.3	4.48	0.06	NA[n]	7.6	?	NA[o]
USA	Clayton[p]	0.023	1.4–1.5	0.76–1.8[q]	1.3	0.08	?	?	?	∼1966
USA	Searles	0.0065	125	1	?	0.1	35	8	1.3	1936[r]
USA	Great Salt	∼0.004	250	1.8	?	?	NA	?	1.218	NA
USA	Salton Sea[s]	∼0.02	1.3	1.8	NA	0.017	?	NA	1.2	NA
Canada	Fox Creek[t]	∼0.01	∼10	?	NA	4	6–7	NA	?	NA
USA	Smackover[t]	∼ 0.037	∼20	?	NA	?	?	NA	1.2	NA

[a]Elevation
[b]Porosity
[c]density
[d]Commenced
[e]Argentina
[f]Hombre Muerto
[g]top 40-50m
[h]Currently at planing stage
[i]The current plan
[j]disputed, value is the average for the upper 25 m (Garrett, 2004)
[k]disputed, there are claims the porosity is ∼0 after 35-40m (Garrett, 2004)
[l]Including Taijinaier
[m]pilot plant commencement date
[n]believed to be a lake
[o]project appears to have stalled
[p]Silver Peak
[q]literature reports a wide range of estimates
[r]Ceased 1978
[s]Geothermal brine
[t]Oil field brine

Table 1.8: Ore deposit information

Country	Deposit	Type	kt Li	wt.% Li	Mine type	Commenced date
Australia	Greenbushes	Spod.[a]	223	1.9	Open cut	1982
Australia	Mt Marion	Spod.[a]	29.8	0.65		∼2010

Table 1.8: (continued)

Country	Deposit	Type	kt Li	wt.% Li	Mine Type	Commenced date
Australia	Mt Cattlin	Spod.[a]	56	0.5	Open cut	∼2010
Austria	Koralpe	Spod.[a]	10	0.78		NA
Brazil	Country	Var.[b]	43	?		1943[c]
Canada	Bernic Lake	Spod.[d]	19	1.28	Room and Pillar	1984[e]
Canada	Wekusko	Spod.[d]	54	0.79		NA
Canada	La Corne	Spod.[d]	163	0.52	Open cut	2012
Canada	La Motte	Spod.[a]	23	0.5	Open cut	NA
Canada	Sep. Rapids	Pet.[f]	56	0.62–0.7	Open cut	NA
China	Jaijika	Spod[a]	240	0.6		NA
China	Yichun	Lepid.[g]	160	∼2	Open cut	Unknown[h]
Finland	Country	Spod[d]	15	0.5		∼2010
FSU	Country	Ore[i]	130	?		1973[j]
Mali	Country	S.+A.[k]	4	1.4		1956[l]
Namibia	Country	Var.[m]	10	0.93		1930[n]
Portugal	Country	Var.[b]	10	0.37–0.77		1925
South Africa	Country	Spod.[a]	15	?		1950[o]
USA	North Carolina[p]	Spod.[a]	230	0.7	Open cut	1943[q]
USA	North Carolina[r]	Spod.[a]	1000	0.7		NA
Zaire	Manono	Spod.[a]	1500	∼0.6		NA
Zimbabwe	Bikita	Var.[b]	23	1.4?		1948
USA	McDermitt	Hectorite	1000	0.33	Open cut	∼2014
USA	Rest	Hectorite		?		
Serbia	Country	Jadarite	425	0.84		

[a] Spodumene
[b] Various ores including amblygonite, lepidolite, petalite and spodumene
[c] first year of recorded production
[d] Mostly spodumene, although other minerals exist as well
[e] production halted in 2009
[f] Mostly petalite, although other minerals exist as well
[g] Lepidolite
[h] currently operating
[i] unknown
[j] may have been producing before 1973
[k] Spodumene and Amblygonite
[l] ceased in 1970
[m] Petalite, amblygonite and lepidolite
[n] production statistics ceased in 1998, and presumably the mine did too
[o] production ceased 1974
[p] Developed
[q] production ceased in 1998
[r] Undeveloped

TABLE 1.7. Analysis of brines in wt.%

		Na	K	Mg	Ca	Li	Cl	SO_4	CO_3	HCO_3	B	Br	pH
Arg.[a]	H. Muerto[b]	9.8	0.6	0.09	0.05	0.06	15.9	0.82			0.035		∼7
Arg.[a]	Rincon	9.630	0.624	0.284	0.041	0.033	15.250	1.014			0.0275		
Arg.[a]	Olaroz		0.55	0.187		0.67							
Arg.[a]	Cauchari	9.33	0.42	0.145	0.033	0.051	14.86	1.57		0.067	0.112		
Bolivia	Uyuni	8.2	0.66	0.64	0.0456	0.0321	14.8	1.08		0.0333	0.0204	0.0049	7.25
Chile	Atacama Low	6.5	1.79	0.93	0.03	0.15	15.66	0.8		0.023	0.04	0.005	
Chile	Atacama High	9.1	3.13	1.3	0.053	0.242	18.95	1.9		0.06	0.0685	0.005	
Chile	Maricunga												
China	Zhabuye	10.66	3.83	0.001		0.067	12.3	2.19	3.23		0.45	0.074	10.86
China	Qinghai[c]	7.77	0.36	1.17	0.03	0.0182	14.16	2.04		0.21	0.081	0.008	7.4
China	DXC[d]	5.16	1.0	0.0086	0.26	0.034	7.15	0.54	1.03	0.18	0.079	0.22	
USA	Clayton[e]	6.2	0.53	0.033	0.02	0.023	10.06	0.71			0.008	∼0.0025[f]	∼7.2[f]
USA	Searles[g]	11.46	2.05		0.0016[h]	0.0057	11.56	4.53	3.28		0.356	0.069	
USA	Great Salt Low	3.7	0.26	0.5	0.016	0.0018	7	0.94	0.0005	0.06	0.0018	0.0055	
USA	Great Salt High	8.7	0.72	1	0.036	0.004	15.6	2	0.0005	0.06	0.006	0.0055	
USA	Salton Sea[i] Low	5	1.3	0.07	2.26	0.01	14.2	0.0042			0.04	0.0109	4.6
USA	Salton Sea High	7	3.42	0.57	3.9	0.04	20.9	0.005			0.05	0.02	5.5
Canada	Fox Creek[j] Low	3.31	0.36	0.082	1.13	0.0096	7.85	0.0129		0.019	0.015	0.026	6.76
Canada	Fox Creek High	4.5	0.63	0.168	2.29	0.011	10.43	0.065		0.093	0.23	0.036	8.1
USA	Smackover[k] Low	5.49	0.24	0.29	2.91	0.0146	14.45	0.0375	0.0123	0.263			
USA	Smackover High	6.7	0.59	0.34	3.45	0.0386	17.17	0.045	0.0366	0.313			

[a]Argentina
[b]Hombre Muerto
[c]Including Taijinaier, values are for the surface of Da Qaidam
[d]assumed a density of 1.2 g/L
[e]Silver Peak from Pavlovic and Fowler (2004) unless stated otherwise
[f]Average of values
[g]average of upper and lower
[h]upper lake only
[i]Geothermal brine
[j]Oil field brine, assumed density of 1.2
[k]Oil field brine

1.4. Conclusions

This report has compiled available reserve and production statistics globally. Australia is a key player in the supply of lithium from spodumene mining to both the glass and battery market. Further work is required to assess - for example, using life cycle assessment - the impacts of lithium production from spodumene and brines as part of evaluating Australia's competitive position to supply the global market. As this market will be increasingly defined by the 'clean' image of electric vehicles, ensuring a clean chain of custody will be imperative for operations seeking both a future licence to operate (at site level) and licence to market (to final end uses of lithium). The future role of lithium recycling also requires further assessment as outlined by Carles (2010).

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APPENDIX A

Afghanistan

Garrett (2004) states that there is potentially a large spodumene deposit in the Hindukush mountain range.

APPENDIX B

Argentina

There are five major salars in Argentina, namely Hombre Muerto B.1.1, Rincon B.1.2, Olaroz B.1.3, Cauchari B.1.4 and Mariana B.1.5. Argentina also has some ore deposits of Lithium. In addition to the information Kunasz (2006) indicates that Argentina has lithium bearing clays at 0.14% lithium at Turilari playa.

B.1. Brines

B.1.1. Hombre Muerto.

B.1.1.1. *General.* FMC operates at the Salar de Hombre Muerto (Kunasz, 2006). The surface area of the Salar is 565km^2, the average depth is 15m and the porosity is 15% (Garrett, 2004). The lithium content of the Salar is 0.062% Li (Tahil, 2007; Evans, 2008a; Pavlovic and Fowler, 2004) although Harben and Edwards (1997) indicates it is 0.065% lithium and reaches 0.068% once KCl is removed. Garrett (2004) states the initial brine concentration is 0.22 g/L lithium, and is concentrated to 1.08 g/L (650 ppm). The Mg:Li ratio is 1.37 Tahil (2007); Pavlovic and Fowler (2004); Yaksic and Tilton (2009). The Salar is located 4300 m above sea level (Garrett, 2004) or 4025 m (Kunasz, 2006) or 3,700 m (Tahil, 2007). The evaporation rate for the salar is estimated at 2,600–2,800 mm/y (Yaksic and Tilton, 2009; Pavlovic and Fowler, 2004), although Harben and Edwards (1997) and Garrett (2004) indicate it is lower at 2,300 mm/y. Garrett (2004) also claims the evaporation rate is 1500 mm/y. Kunasz (2006) indicates the lithium concentration is 200–2000 ppm, however Garrett (2004) states it is 190 - 900 ppm (521 ppm average). The analysis of the brine is shown in the Table B.1 from Garrett (2004). The conductivity of the brine ranges from 1.68 to 1.80 mho/cm (Garrett, 2004). Pavlovic and Fowler (2004) stated the brine has a density of 1.205 g/mL.

B.1.1.2. *Resources/Reserves.* Harben and Edwards (1997) indicated that Salar de Hombre Muerto reportedly contains 130,000 tonnes of lithium. Garrett (2004) stated the reserves are 800,000 tonnes of lithium. Kunasz (2006) indicates that FMC has a reserve life of 75 years. Tahil (2007) assuming the 75 year reserve life, and a production rate of 5000 tonnes per year of metal estimates a reserve of 375,000 tonnes of lithium. Evans (2008a) indicated that the Salar de Hombre Muerto has 850,000 tonnes of proved and probable reserves. Yaksic and Tilton (2009) indicated the Salar de hombre Muerto has reserves of 815,000 tonnes of lithium. Gruber and Medina (2010) calculated the lithium in the brine and estimated the Salar had a resource of 800,000 tonnes of lithium, this would appear to confirm the estimate from Tahil (2007). Gruber and Medina (2010) quoting from the full report of Clarke and Harben (2009) stated that Clarke and Harben have a reserve estimate of 0.808 Mt of lithium for Hombre Muerto.

TABLE B.1. Analysis of the brine at Salar de Hombre Muerto (Garrett, 2004; Wietelmann and Bauer, 2000; Pavlovic and Fowler, 2004)

Location	Na	K	Ca	Mg	Li	Cl	SO_4	B_2O_3	T.S.[a]	ρ^b	pH
A[c] (ppm)	15	76	210	72	2.1	900	1100	25	3500	1.001	7.5
B[d] (wt%)	9.45	0.55	0.02	0.16	930[e]	15.8	1.06	1400[e]	28	1.22	7.2
C[f] (wt%)	10.1	0.519	0.088	0.054	521[eg]	16	0.846	750[e]	27.8	1.204	6.9
Range low	9.9	0.24	0.068	0.018	190[e]	15.8	0.53	260[e]	27.2	1.199	6.5
high (wt.%)	10.3	0.97	0.121	0.141	900[e]	16.8	1.14	1590[e]	29.4	1.212	7.2
D[h] (wt.%)	9.8	0.6	0.05	0.09	0.06	15.9	0.82				
E[i] (wt.%)	9.789	0.617	0.053	0.085	0.062	15.8	0.853	0.035[j]		1.205	

[a]Total Solids
[b]Density
[c]Initial brine at Catal Lagoon
[d]Catal Lagoon at NaCl saturation
[e]ppm
[f]Average brine in top 1m of sediment
[g]also 29 ppm Rb and 33 ppm Cs
[h]Hombre Muerto, from Wietelmann and Bauer (2000)
[i]Hombre Muerto, from Pavlovic and Fowler (2004)
[j]as B

B.1.2. Rincon.

B.1.2.1. *General.* The Salar was initially worked on by Admiralty Resources under a wholly owned subsidiary called Rincon Lithium, and they established a pilot plant in 2008 Admiralty Resources (2008). However Admiralty resources have recently sold Rincon Lithium to Sentient GP for US $22.17 million Admiralty Resources (2009). The Salar has a surface area of 250–280 km^2 (Gruber and Medina, 2010). Gruber and Medina (2010) estimated that the Salar has an average depth of 30m and a porosity of 30%, however Anon (2007) stated the maximum depth is 60m with an average of 40m and the porosity is 23%.

The lithium content of the Salar is disputed with Pavlovic and Fowler (2004) and Evans (2008a) stating 0.033% lithium, Yaksic and Tilton (2009) indicating 0.04 % lithium and Wietelmann and Bauer (2000) indicating 0.05 % lithium. The Mg:Li ratio is rather high at around 8.5–8.61 (Yaksic and Tilton, 2009; Evans, 2008a; Pavlovic and Fowler, 2004). The Salar is located 3,700 - 3740 m above sea level (Tahil, 2007; Evans, 2008a). The evaporation rate is 2,600 mm/y (Yaksic and Tilton, 2009). Pavlovic and Fowler (2004) indicates that the high Mg:Li ratio and a SO_4:Li ratio of 30.7:1 make lithium recovery unfavorable via conventional methods. The density is 1.204 g/mL (Pavlovic and Fowler, 2004). The brine concentrations for the Salar de Rincon is shown in Table B.2.

B.1.2.2. *Resources/Reserves.* Pavlovic and Fowler (2004) has determined that the recoverable resources of lithium are 480,000 tonnes (Table B.3); however plant processing losses make the recovery 40-42% of this value. Pavlovic and Fowler (2004) estimates this value by using an average lithium concentration of 0.4 g/L, a 200 km^2 area of the Rincon nucleus, a depth of 60 m, and a porosity of 10%.

TABLE B.2. Analysis of the brine at Salar de Rincon in wt.% (Pavlovic and Fowler, 2004; Wietelmann and Bauer, 2000)

Location	Na	K	Ca	Mg	Li	Cl	SO_4	B	ρ^a
Rincon[b]	9.630	0.624	0.041	0.284	0.033	15.250	1.014	0.0275	1.204
Rincon[c]	10.8	0.7	0.12	0.4	0.05	16.7	0.7		

[a]Density
[b]Pavlovic and Fowler (2004)
[c]Wietelmann and Bauer (2000)

TABLE B.3. The analysis of the Salar de Rincon Pavlovic and Fowler (2004)

Element	grade (g/L)	Resources (Mt)
K	7.51	9.012
Li	0.4	0.48
Mg	3.42	4.104
B_2O_3	1.07	1.284
SO_4	12.21	14.652

Admiralty Resources (2007) indicated 1.4 million tonnes of lithium of JORC compliant reserves, up from the previous JORC compliant resource of 70,000 tonnes of lithium, shown in Table B.4 from Tahil (2008). Yaksic and Tilton (2009) using Admiralty Resources (2007) estimate indicates that the Salar de Rincon has in-situ resources of 1,870,000 tonnes of Li, and expects a 75% recovery so that 1.4 million of Lithium is recoverable resources. Gruber and Medina (2010) quoting the full report from Clarke and Harben (2009) stated that Clarke and Harben has 1.4 million tonnes of lithium reserves.

TABLE B.4. JORC reserves of lithium in tonnes for Salar de Rincon Tahil (2008)

Reserves	Low	Expected	Uncertainty	High
Proven	746,000	911,000	53,000	1,098,000
Probable	288,000	492,000	72,000	762,000
Total	1,035,000	1,403,000	26,000	1,861,000

Tahil (2008) claims indicated reserves are actually 250,000 tonnes of lithium, though this is disputed by Evans (2008b). Gruber and Medina (2010) estimated a resource of 1.118 Mt of lithium.

B.1.3. Olaroz.

B.1.3.1. *General.* Orocobre is the mining company that is looking to exploit lithium resources in the Salar de Olaroz. Orocobre (2009) estimate that capital costs will be US$80-100 million. The lithium content of the Salar is 0.09% lithium (Yaksic and Tilton, 2009). The Mg:Li ratio is disputed, with Yaksic and Tilton (2009) estimating a value of 2, whereas Orocobre (2008) indicated 2.2 and later revised this figure to 2.8 (Orocobre, 2009). Although the Mg:Li ratio halves with evaporation (Orocobre, 2008). The resource extends to an average depth of 55m (Orocobre, 2009). (Orocobre, 2009) indicate that the Salar is close to the Hombre Muerto and that hence the evaporation rate should be similar (2,600-2,800 mm/y). The Salar has a surface area of 118 km^2, an average grade of 800mg/L lithium and the porosity for the top 40-50 m is 6-8% (Orocobre, 2010a). Initial production is aimed at 15,000 tonnes per year of lithium carbonate (2,820 tonnes/y lithium) and 36,000 tonnes per year of potash (Orocobre, 2009). (Orocobre, 2008) stated that the average concentration is 650 ppm lithium, and 1.7% potassium chloride and that over the total project area the lithium concentration varies from 282 ppm to 1207 ppm. Gruber and Medina (2010) estimated that the density is 1.2 g/mL. A partial analysis of the brine indicated concentrations of 0.8 g/L for lithium, 6.6 g/L for potassium and 2.24 g/L for Magnesium (Orocobre, 2010b).

B.1.3.2. *Reserves/Resources.* Tahil (2008), assuming a lithium concentration of 900 ppm, and 10% porosity estimated a lithium resource of 325,000 tonnes. Tahil (2008) further indicates that production from the Salar is 5 years away. Orocobre (2009) has estimated the inferred resources to a depth of 55m as shown in Table B.5. A lithium carbonate of 1.49 million tonnes is approximately 280,000 tonnes of lithium. Yaksic and Tilton (2009) stated the resource is 325,000 tonnes of lithium. Gruber and Medina (2010) quotes the full report of Clarke and Harben (2009) that stated the resources are 560,000 tonnes of lithium. Gruber and Medina (2010) estimated the resources of Salar and estimated a value of 156,000 tonnes of lithium.

TABLE B.5. inferred resources in Salar de Olaroz (Orocobre, 2009)

Estimate	brine GL	Li g/L	K g/L	Potash tonnes	Li tonnes	Ave. Specific yield Zone 1	Zone 2
Preferred	350	0.8	6.6	4,400,000	280,000	11.5%	8.3%
Higher	415	0.8	6.6	5,220,000	332,000	13.3%	9.9%
Lower	225	0.8	6.6	3,230,000	204,000	9.0%	6.0%

B.1.4. Cauchari. This brine deposit is owned by Lithium America (Lithium America, 2010). The brine's lithium concentration ranges from 200–2150 mg/L (Lithium America, 2010). The inferred resources are estimated at 926,000 tonnes of lithium metal (Lithium America, 2010; King, 2010). The aim is to have a pilot plant operating in 2011 (Lithium America, 2010). The Mg:Li ratio is 2.84 (Lithium America, 2010). The average density is 1.215 g/ml (King, 2010). The salar has an elevation of 3950 m (King, 2010). The lithium concentration is estimated at 0.051 wt% (King, 2010). The analysis of the brine is shown in Table B.6.

B.1.5. Mariana. The area of the brine is 120 km^2 and is located in the Salar de Llullaillaco (TNR, 2010a). TNR (2009) indicates that seven shallow brine samples had lithium concentrations in the range of 188 - 283 mg/L lithium. The lithium concentration was estimated at 250-650 mg/L and a concentration plot is shown in Figure B.1 TNR (2010a). TNR Gold intends to spend 2011 looking at the feasibility of mining the resource (TNR, 2010a).

TABLE B.6. The analysis of the Cauchari brine (King, 2010)

Component	wt.%
Na	9.33
K	0.42
Li	0.051
Mg	0.145
Ca	0.033
SO_4	1.57
Cl	14.86
HCO_3	0.067
B	0.112
Density	1.215
Mg:Li	2.84

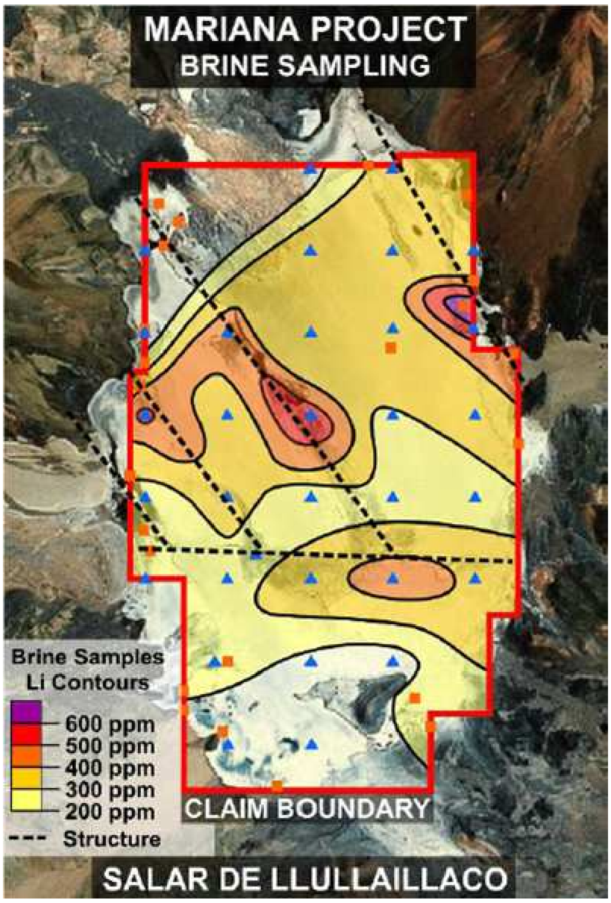


FIGURE B.1. The concentration plot for the Mariana project (TNR, 2010a)

B.1.6. Salinas Grandes. Orocobre owns this deposit. The deposit has a 60 km^2 nucleus (Orocobre, 2010b). The brine has concentrations of: 0.775 g/L lithium, 2.24 g/L magnesium 9.289 g/L potassium and 0.232 g/L for boron and the Mg:Li ratio is 2.73 (Orocobre, 2010b).

APPENDIX C

Austria

C.1. Ore

C.1.1. Koralpe. Austria has a deposit of spodumene at Koralpe. The deposit is approximately 270 km south west of Vienna (Göd, 1989). Göd (1989) states the grade is 1.68% lithia (0.78% lithium). Anstett et al. (1990) states the grade is 0.65% lithium or 0.77% lithium (both values cited in text in different sections). The spodumene has 7.4% lithia (3.4% lithium) and an FeO content of 0.45%. The geological map of the deposit is shown in Figure C.1.

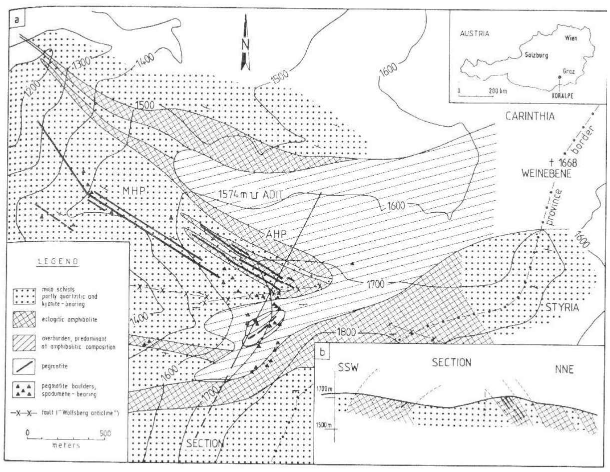


FIGURE C.1. Geological map of the Koralpe deposit (Göd, 1989)

Initially the U.S. Bureau of Mines (var) indicted that the reserves were 5,500 tonnes of spodumene at 1.7% Li2O (0.8% Li) in 1984. In 1985, this was increased to 11 million tonnes of spodumene reserves at 1.6% lithia (0.73% lithium). Anstett et al. (1990) indicated that uneconomical and extensions of known deposits resources are 13 million tonnes of ore, estimated in 1986. Using 0.65% Li, Anstett et al. (1990) obtains a value of 84,500 tonnes of lithium resources. Evans (2008a) obtains a contained lithium resources value of 100,000 tonnes which is correct if 0.77% value is used. Wietelmann and Bauer (2000) claims the contained ore is 5 million tonnes, though this is from a reference dated 1984, and hence is probably no longer valid. Wietelmann and Bauer (2000) states the grade is 0.77% Li. Garrett (2004) states that the deposit has 10 million tonnes of ore at 0.77% lithium (77,000 tonnes of lithium) and states the reserve is 10,000 tonnes of lithium. Gruber and Medina (2010) stated the resources are 100,000 tonnes of lithium.

APPENDIX D

Australia

D.1. Ore

Anstett et al. (1990) has some reserve and resource numbers for Australia, which is probably based on Greenbushes numbers. Anstett et al. (1990) states the identified economic resources are 41.9 million tonnes of ore, at an average grade of 1.36% lithium. The identified economic resources are 569,800 tonnes of lithium, and the recoverable amount is estimated at 313,000 tonnes of lithium (Anstett et al., 1990). Tahil (2007) estimated Australia's lithium reserves at 160,000 tonnes of lithium and a reserve base of 260,000 tonnes of lithium.

D.1.1. Greenbushes.

D.1.1.1. *General.* The ore is excavated using drill and blasting technique (Garrett, 2004). Tahil (2008) and Ebensperger et al. (2005) indicate the raw ore has a concentration of 4% lithia (1.9% lithium) whereas Garrett (2004) states that the raw ore has a grade of 2.02% lithium. Harben and Edwards (1997) states that Greenbushes produces to concentrate grades one 7.5% lithia concentrate (3.5% lithium) and a 4.5% Lithia concentrate (2.1% lithium). Garrett (2004) states that in 1993, the overburden ratio was 1.8:1 and the ore grade was 1.86% lithium. The overburden is weathered clay and is on average 20 m with a maximum of 60 m. Garrett (2004) states the spodumene has a concentration of 4.01% Lithia (1.9% lithium), and that many lithium zones have 2.32% lithium. Tahil (2008) claims it is 4.8% lithia concentrate (2.2% lithium). Ebensperger et al. (2005) indicated that spodumene is concentrated to around 5.5% lithia (2.6% lithium), and that production capacity in 2001 was 150,000 tonnes of concentrated ore though sales are only 80,000 tonnes. According to Garrett (2004) iron is the most harmful impurity to quality. The side view of the deposit is shown in Figure D.1.

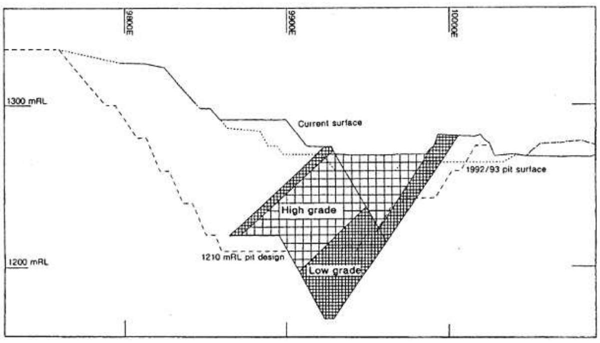


FIGURE D.1. Side view of the Greenbushes deposit (Garrett, 2004)

Garrett (2004) states that the glass grade product contained 2.23 - 2.32% lithium and less than 0.13% iron oxide. In 1993, the concentrate grade contained 3.49% lithium, and 0.1% iron oxide. The initial iron oxide concentration in 0.94% (Garrett, 2004).

Kunasz (2006) indicates that Greenbushes initially had a capacity of 30,000 tonnes per year in 1985, and that it was increased to 100,000 tonnes per year in 1993-94, and 150,000 tonnes per year in 1996-97. Anstett et al. (1990) indicates Greenbushes has a production capacity of 510 tonnes of lithium per year. Harben and Edwards (1997) state that in 1994 the production capacity of spodumene was increased to 150,000 tonnes per year. Garrett (2004) states that the production capacity in 1998 - 2002 was 150,000 tonnes per year.

D.1.1.2. *Reserves/resources.* Harben and Edwards (1997) stated that Greenbushes has 30 million tonnes of reserves, with at least 6 million tonnes of reserves with a lithia concentration of 4% (1.9% lithium). Wietelmann and Bauer (2000) indicated Greenbushes has reserves of 0.7 million tonnes of lithium, of which 10% is $>$4% lithia (1.9% lithium) 50% is $>$2.5% lithia (1.2% lithium) and 40% is $>$1.5% lithia (0.7% lithium). Wietelmann and Bauer (2000) also stated that there is 4 million tonnes of lithium as potential reserves. Garrett (2004) states that ore reserves are 42 million tons (believe 38 million metric tonnes) at 1.36% lithium (571,000 tonnes of lithium) and 7.9 million metric tonnes of ore at 2.02% lithium (159,000 tonnes of lithium). Garrett (2004) stated the reserves are 150,000 tonnes of lithium. Kunasz (2006) indicated Greenbushes spodumene reserves and resources are greater than 13 million tonnes of ore. Evans (2008a) estimates that Greenbushes has proved, probable and possible reserves of 223,000 tonnes of lithium. Yaksic and Tilton (2009) states the resources of Greenbushes are 255,000 tonnes of lithium. Gruber and Medina (2010) stated that the full report of Clarke and Harben (2009) estimated a resource of 1.5 Mt of lithium. Gruber and Medina (2010) stated that Talison has 35.5 Mt of ore at a grade of 3.31% (1.54%) hence a lithium resource of 560,000 tonnes of lithium.

D.1.2. Mt Marion.

D.1.2.1. *General.* Reed resources in partnership with Mineral Resources, is planning to start production on the Mt Marion deposit in 2010 at 200,000 tonnes per annum of ore concentrated to 6.5% lithia ($\sim$6,000 tonnes per year of lithium) (Batten, 2010). Mt Marion spodumene deposit has a grade of 1.5-2% (believed lithium oxide) (Reed Resources, 2009).

D.1.2.2. *Reserves/Resources.* Kunasz (1983) stated that Mt Marion has reserves in excess of 1 million tonnes of ore. Evans (2008a) estimated that Mount Marion has total reserves of 19,800 tonnes of lithium. Yaksic and Tilton (2009) state that Mt Marion has 19,800 tonnes of lithium resources. Mt Marion has indicated and inferred resources of 8.92 million tonnes at 1.4% lithia (0.65% lithium) or 128,045 tonnes of lithia (59,540 tonnes of lithium) (Batten, 2010).

D.1.3. Mt Cattlin.

D.1.3.1. *General.* Galaxy Resources are planning to commence mining at Mt Catlin in 2010 (Galaxy Resources, 2009). The average grade of the resource is around 1.08% lithia (0.5% lithium) (Galaxy Resources, 2009). The mine is anticipated to have a mine life of 16 years and will be capable of producing 137,000 tonnes of Spodumene concentrate a year Galaxy Resources (2009).

D.1.3.2. *Reserves/resources.* Evans (2008a) estimates that Mount Catlin reserves are 20,000 tonnes of lithium. Tahil (2008) indicates that Mount Cattlin has 24.8 Mt of ore at 0.56% lithia (0.26% lithium), or 65,000 tonnes of lithium in the ground. Tahil (2008) believes that of these resources, roughly 28,000 tonnes of lithium is recoverable. Yaksic and Tilton (2009) states Mt Cattlin has 64,500 tonnes of lithium resources. The mine has proven and probable reserves of 11.4

million tonnes of ore (∼55,500 tonnes of lithium) see Table D.1 (Galaxy Resources, 2009). Total resources are in the region of 16 million tonnes as shown in Table D.2 although lithium is believed to exist in deposits beyond where the resources where measured (Galaxy Resources, 2009).

TABLE D.1. Mt Catlin reserves (Galaxy Resources, 2009)

Reserves	Ore Tonnes	Grade Li_2O%	Lithium Tonnes
Proved	2,683,000	1.08	13,500
Probable	8,684,000	1.04	42,000
Total	11,367,000	1.05	55,500

TABLE D.2. Mt Catlin resources (Galaxy Resources, 2009)

Reserves	Ore Tonnes	Grade Li_2O%	Lithium Tonnes
Measured	2,672,000	1.17	14,500
Indicated	9,629,000	1.09	48,800
Inferred	3,575,000	1	16,600
Total	15,875,000	1.08	79,700

APPENDIX E

Bolivia

E.1. Brine

E.1.1. Salar de Uyuni.

E.1.1.1. *General.* Bolivia has a large and so far unexploited lithium deposit in the Salar de Uyuni. The Salar has a surface area of 9000–10,500 km^2 (Garrett, 2004). The lithium content of the Salar is disputed, with Kunasz (2006) and Anstett et al. (1990) indicating 0.025%, Wietelmann and Bauer (2000) indicating 0.024%, Pavlovic and Fowler (2004) estimating 0.035% and Yaksic and Tilton (2009) estimating 0.04% lithium. Moores (2009a) states the 0.035% (0.423g/L) value was originally from the USGS. The lithium content has been stated to be 0.045% lithium (0.542 g/L) (Moores, 2009a). The density of the brine is 1.211 g/mL (King, 2010) or 1.217 g/mL (Gruber and Medina, 2010).

The Mg:Li ratio is disputed but is very high, in particular Pavlovic and Fowler (2004) estimates 18.6:1, Yaksic and Tilton (2009) 19:1, Kunasz (2006) 21.5:1, Evans (2008a) has a value of 22:1 and Mapstone (2010) states it is 30:1.

The Salar is at 3653 m above sea level (Kunasz, 2006; Garrett, 2004; Risacher and Fritz, 1991) and the salt crust is 15-20 m thick (Kunasz, 2006) although Tahil (2008) stated the maximum depth was 11m. The Salar has been estimated to have 100-700 ppm lithium (Kunasz, 2006) with an average of 321 ppm (Garrett, 2004). Tahil (2008) has salt depth and lithium concentration maps for the Salar de Uyuni shown in Figures E.1 and E.2. Garrett (2004) has the analysis of the brine shown in Table E.1. The evaporation rate is 1,500 mm/y (Yaksic and Tilton, 2009). Tahil (2008) estimates the porosity is 35%, and Risacher and Fritz (1991) states the average porosity is 30-40%. Moores (2009a) states that the high Mg:Li ratio, low evaporation rate and season flooding raises doubts over the project.

Moores (2009a) states that the Bolivian government under Corporacion Minera de Bolivia (COMIBOL) is aiming to have a 20,000-30,000 tonnes per year of lithium carbonate (3,760-5,640 tonnes per year of lithium) plant in production by 2012. The plant is predicted to cost Bolivia $250-300 million (US?) (Moores, 2009a). (Moores, 2009b) states that Bolivia currently has a small pilot plant in operation, and that Bolivian and South Korean governments have agreed to develop the resource. Mapstone (2010) states that production is slated for 2014.

E.1.1.2. *Resources/Reserves.* Anstett et al. (1990) estimates marginally economic in-situ resources are 101,000 tonnes of lithium, sub-economic in-situ resources are 25,000 tonnes of lithium and extensions of known deposit in-situ resources are 5,374,000 tonnes of lithium. Risacher and Fritz (1991) estimated that the salar had a resource of 9 Million tonnes of lithium. Garrett (2004) states that the reserves are 5 million tonnes, however he also states that the brine contains 5.5

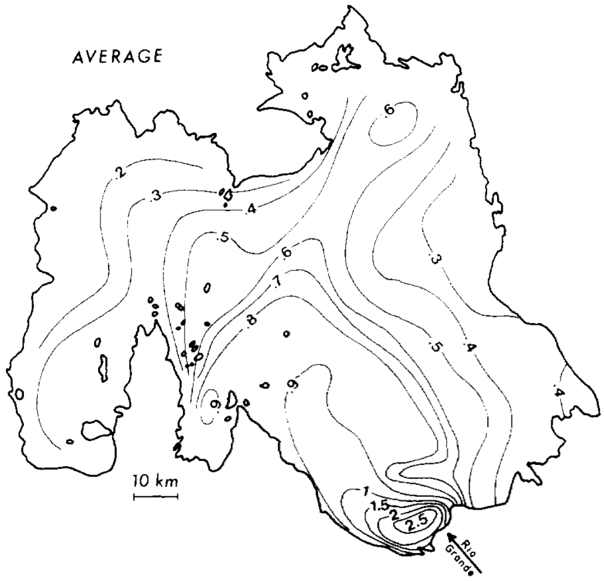


FIGURE E.1. The concentration of lithium in the Salar de Uyuni in g/L (Risacher and Fritz, 1991)

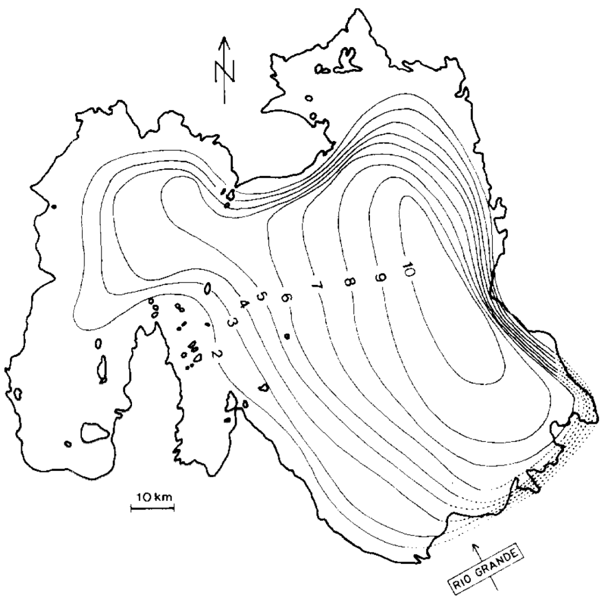


FIGURE E.2. The depth of the Salar de Uyuni in meters (Risacher and Fritz, 1991)

million tonnes of lithium. Tahil (2007) indicates the reserves are 2.7 million tonnes and the reserve base is 5.4 million tonnes. Evans (2008a) and Yaksic and Tilton (2009) indicate the Uyuni has 5.5 million tonnes of lithium reserves, which is based on the work by Ballivian and Risacher (1981). Mineral Commodity Summary (var) indicates the reserve base is 5.4 million tonnes of lithium. Moores (2009a) states the resources may be as much as 8.9 million tonnes of lithium. Gruber and Medina (2010) estimates that the Salar contains 10.2 Million tonnes of lithium resources. COMIBOL has stated that the resources are 350 million tonnes of lithium, and that realistic reserves are 140 million tonnes of lithium (COMIBOL, 2010). The estimate by COMIBOL does not appear to be accurate, unless the concentration or depth of Salar has been incorrectly determined.

TABLE E.1. The analysis of the Salar de Uyuni brine (Garrett, 2004; Pavlovic and Fowler, 2004; Wietelmann and Bauer, 2000)

Component	Unit	Average[a]	Individual sample	Average[b]	Pavlovic[c]	Ullmanns[d]
Na	wt.%	8.2	8.72	7.06	8.8	9.42
K	wt.%	0.66	0.72	1.17	0.72	0.51
Mg	wt.%	0.64	0.65	1.25	0.65	0.44
Ca	ppm	456	463	306	460	0.05
Li	ppm	321	349	625	350	0.024
Sr	ppm		14			
Cl	wt.%	14.8	15.71	5	15.7	15.91
SO_4	wt.%	1.08	0.85			0.72
HCO_3	ppm		333			
B	ppm	187	204	525	200	
Br	ppm		49			trace
F	ppm		10			
SiO_2	ppm		7			
pH			7.25	7.3		
Density	g/L		1.21	1.19		

[a]of 40 samples
[b]of 8 high lithium samples
[c]Pavlovic and Fowler (2004)
[d]Wietelmann and Bauer (2000)

E.1.2. Salar de Copaisa. The salt flat has a surface area of 2500 km^2 at an altitude of 3656m (Risacher and Fritz, 1991). Tahil (2008) indicates that it contains 200,000 tonnes of Lithium and Evans (2008a) indicates the lithium concentration is 580 ppm. Garrett (2004) has the analysis of the brine shown in Table E.2. A map showing the location of the Salar de Copaisa relative to the Salar de Uyuni is shown in Figure E.3

E.1.3. Salar de Pastos Grandes. New World Resources owns the rights to the Salar de Pastos Grandes (Lando, 2010). The salar has an area of 125 km^2 and an elevation is 4,200 m (Lando, 2010). New World Resources has access to 75 km^2 of the Salar (Lando, 2010). The average grade is 1033 ppm lithium (Lando, 2010). The Mg:Li ratio is around 2.24 (Lando, 2010). A partial brine analysis is shown in Table E.3.

TABLE E.2. The analysis of the Salar de Copaisa brine (Garrett, 2004)

Component	Unit	Individual sample	Average[a]
Na	wt.%	7.51	71[b]
K	wt.%	1.1	1.21
Mg	wt.%	1.36	1.36
Ca	ppm	156	227
Li	ppm	350	243
Sr	ppm	17	
Cl	wt.%	15.1	16.5
SO_4	wt.%	2.46	
HCO_3	ppm	747	
B	ppm	786	
Br	ppm	142	
F	ppm	33	
SiO_2	ppm	10	
pH		7.23	
Density	g/L	1.231	

[a]of 4 samples
[b]believed to be a typo in Garrett (2004) and presumably ought to be 7.1

TABLE E.3. The analysis of Salar de Pastos Grandes brine samples (Lando, 2010)

Sample	Li (ppm)	K (ppm)	Mg (ppm)	Mg:Li
1	706.97	4,483.35	956.04	1.35
2	1,202.50	7,950.61	1,868.28	1.55
3	1,341.25	8,769.26	2,167.03	1.62
4	1,787.23	10,170.61	3,660.78	2.05
5	1,489.91	8,721.11	3,063.28	2.06
6	353.48	2,388.55	948.64	2.68
7	806.07	6,794.85	1,220.99	1.51
8	1,430.45	9,178.59	1,967.86	1.38
9	439.38	4,362.96	710.08	1.62
Ave.	1,061.90	6,9780.00	1,840.30	1.76

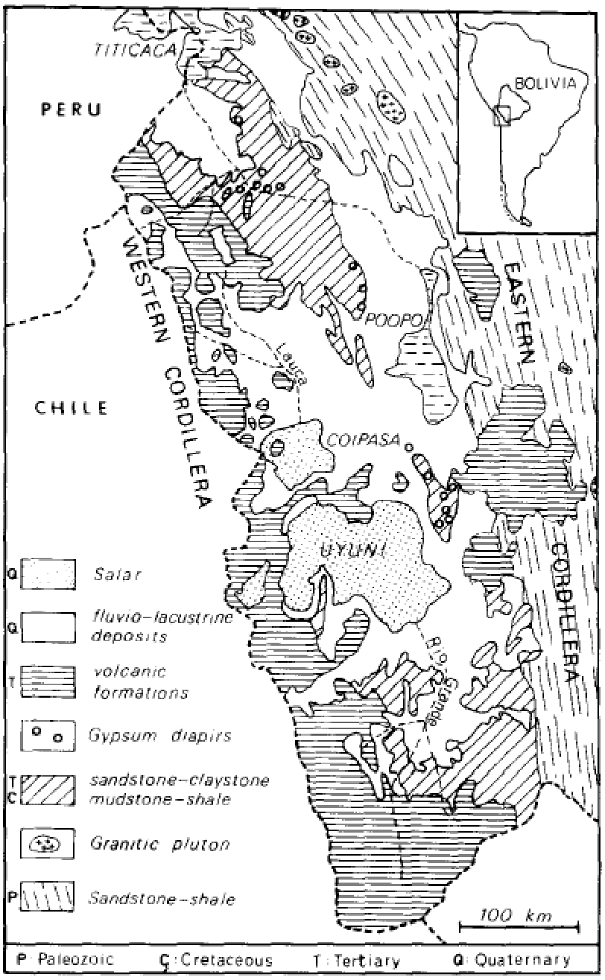


FIGURE E.3. Location of the Salar de Copaisa and Salar de Uyuni (Risacher and Fritz, 1991)

APPENDIX F

Brazil

F.1. Ore

Brazil has four deposits, Solonopole, Quixerambim, Itinga and Aracuai (Anstett et al., 1990). Anstett et al. (1990) indicates that Solonopole and Quixerambim are historic mines that produced amblygonite and lepidolite respectively. Aracuai is a petalite mine and Itinga is an amblygonite, petalite and spodumene mine (Anstett et al., 1990). Anstett et al. (1990) had Brazil's identified economic resources at 215,000 tonnes of ore, and recoverable economic resources at 3,300 tonnes of lithium, with an average grade on 1.92% lithium. Anstett et al. (1990) had uneconomical and indicated resources at 100,000 tonnes of ore, at a grade of 3.96% lithium. Garrett (2004) states the reserves are 3,300 tonnes of lithium. Garrett (2004) further states that 300,000 tonnes of spodumene exists in Aracuai-Itinga area. Kunasz (2006) indicates that exploration found a 100,000 tonnes petalite deposit in Aracuai at 2% lithium and further states that spodumene ore reserves (unknown grade) are 300,000 tonnes. Mineral Commodity Summary (var) in 2002 update reserves for Brazil to 190,000 tonnes of lithium and a reserve base of 910,000 tonnes of lithium. Evans (2008a) reports ore reserves at 85,000 tonnes of lithium, which is referenced to Ramos (2001), unfortunately, Evans (2008a) does not indicate what that reference is. Clarke and Harben (2009) estimates that the reserves of Brazil are 123,000 tonnes of lithium.

APPENDIX G

Canada

Anstett et al. (1990) states that the identified economic resources of Canada are 6.6 million tonnes of ore at 1.28% lithium (84,500 tonnes of lithium) and that recoverable economic resources are 68,000 tonnes of lithium. Anstett et al. (1990) adds that marginal and uneconomic extentions of known deposits have 76 million tonnes of ore, at an average of 0.63% lithium (478,800 tonnes of lithium).

Wietelmann and Bauer (2000) state that Canadian reserves are 0.6 million tonnes of lithium. Garrett (2004) states that Canada has a total reserve of 240,500 tonnes of lithium. Tahil (2007) states that Canada has reserves of 180,000 tonnes of lithium and a reserve base of 360,000 tonnes of lithium.

G.1. Ore

G.1.1. Bernic Lake, Manitoba.

G.1.1.1. *General.* Bernic lake deposit is 175 km North East of Winnipeg in Manitoba near the Separation rapids deposit (Crouse and Černý, 1972). Bernic Lake deposit was mined by Tanco via the room and pillar method (Kunasz, 2006). The deposit was discovered in 1929 as a tin prospect (Cassiterite) (Garrett, 2004). In 1936/37 70 tons (63 tonnes) of lithium ore was produced and in 1940, 100 tons (91 tonnes) of lithium ore was produced (TANCO, 2001). Amblygonite was mined in 1960 (Garrett, 2004). Mining of tantalum began in 1969 and was halted in 1982 (Garrett, 2004). A spodumene pilot plant operated in 1984 to concentrate spodumene from and in 1986 a 15,000 tonne per year spodumene concentrate plant was built (Garrett, 2004). Tantalum was recommenced in 1988, and amblygonite concentrates were separated in 1989 (Garrett, 2004). Harben and Edwards (1997) stated that the amount of amblygonite being produced was small. Garrett (2004) states that petalite and lepidolite is also present and that the lepidolite grade ranges from 0.87 to 1.31% lithium and potentially TANCO could sell the lepidolite. Garrett (2004) stated that ore recovery was 89%. An aerial and side view of the deposit is shown in Figures G.1 and G.2 and the analysis of various minerals is shown in Table G.1. TANCO suspended the Bernic lake mine in September 2009, due to insufficient demand (Moores, 2009c). Yaksic and Tilton (2009) states the grade is 1.28% lithium.

In 1984, saw production of spodumene concentrates of 5% Li_2O (2.3% lithium) commence (Kunasz, 2006). The 15,000 tonnes per year plant (350 tonnes/y of lithium assuming 2.3% lithium or 180 tonnes per year assuming 1.2% lithium) to produce spodumene concentrate was commissioned in 1985 Harben and Edwards (1997). Anstett et al. (1990) stated that the spodumene capacity was 200 tonnes of lithium. In 1991 Tanco was producing 12,000 tonnes per year of low iron lithium ore, as well as amblygonite with 7% lithia and 20% P_2O_5 (Garrett, 2004).

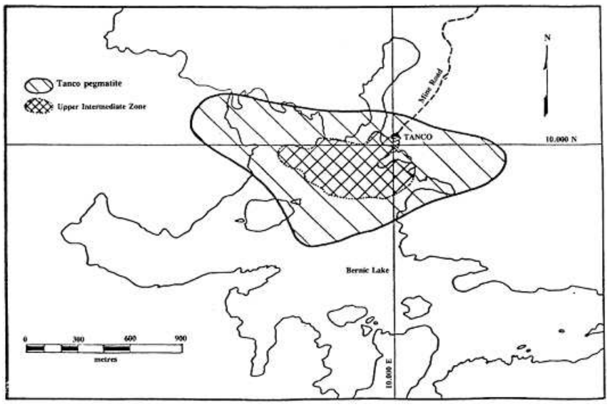


FIGURE G.1. An aerial view of the Bernic Lake deposit (Garrett, 2004)

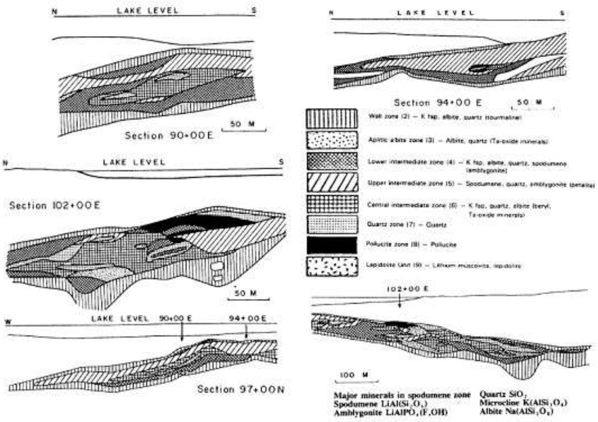


FIGURE G.2. The side view of the Bernic Lake deposit (Garrett, 2004)

Ebensperger et al. (2005) stated that in 2001 the production capacity was 21,000 tonnes of ore with a lithia content of 2.6% (1.2% lithium) (250 tonnes per year of lithium capacity). Jaskula (2008) stated that the production capacity is 24,000 tonnes per year in 2002.

G.1.1.2. *Reserves/Resources.* Garrett (2004) stated that the spodumene reserves in 1984 were estimated at 7.4 million tonnes of ore at 1.34% lithium, hence 99,160 tonnes of lithium reserves. Wietelmann and Bauer (2000) stated that the deposit has 60,000 tonnes (believed to be lithium resources). Garrett (2004) stated that Bernic lake has 73,000 tonnes of lithium reserves. Evans (2008a) states that current reserves are estimated at 18,600 tonnes of lithium. Yaksic and Tilton (2009) state the resources are 18,600 tonnes of lithium.

G.1.2. Wekusko Lake, Manitoba. Garrett (2004) stated that in 1958 there was 10 million tons of ore (8 million tons at Winnipeg river and 2 million tons at Herb Lake). The ore is mainly spodumene with some petalite, lepidolite and amblygonite (Garrett, 2004). Evans (2008a) states that Wekusko Lake has 28,000 tonnes of lithium, and that Snow Lake has 26,000 tonnes of lithium. Wekusko Lake spodumene deposit averages 0.79% lithium (Garrett, 2004). Note, Garrett (2004) places Wekusko Lake in Ontario creating some confusion as to whether or not it is the same deposit.

G.1.3. La Corne, Quebec.

TABLE G.1. The analysis of minerals (wt.%) at Bernic Lake (Garrett, 2004)

	Spod.[a]	SQI[b]	Pet.[c]	Amb.[d]	Mon.[e]	Lith.[f]	Euc.[g]	Lep.[h]	Mus.[i]
Li_2O	7.87	4.48	4.55	9.9	9.52	9.13	11.03	4.7	4.57
SiO_2	63.45	77.08	77.83				45.18	47.85	43.89
Al_2O_3	27.4	16.57	16.58	32.86	35.1		43.79	26.02	36.01
Na_2O	0.114	0.253	0.054	0.047	0.139	0.05		0.16	0.23
K_2O	0.038	0.048	0.05	0.004					
CaO	0.16	0.09	0.008	0.132	0.085	1			
MgO	0.012	0.015	0.028	0.002	0.003	0.51			
Fe_2O_3	0.053	0.13	0.007			8.83		0.11	0.4
MnO						34.39		0.55	0.15
Rb_2O	0.002	0.012						4.29	1.92
Cs_2O	0.001	0.008						0.93	0.25
F				6.3	1.4			4.54	0.38
P_2O_5	0.02	0.05		49.26	49.11	44.95			
H_2O	0.41	0.37	0.41	3.27	5.32			1.76	
Insol.						0.07			

[a]Spodumene
[b]Spodumene, quartz and feldspar mixture
[c]Petalite
[d]Amblygonite
[e]Monebrasite
[f]Lithiophilite
[g]Eucryptite
[h]Lepidolite
[i]Lithian Muscovite

G.1.3.1. *General.* Canada lithium (formerly Black Pearl Minerals) also known as Quebec Lithium, own and are about to recommence mining in the La Corne lithium deposit. The deposit is mostly spodumene with a small amount of lepidolite (Garrett, 2004). The deposit was discovered in 1942 Stone and Selway (2009). The deposit was mined between 1955 and 1965 and had an average grade of 1.25% lithia (0.58% lithium) (Canada Lithium, 2010). Production ceased for one year in 1959 (Stone and Selway, 2009). The analysis of the spodumene concentrate is shown in Table G.2.

Stage 1 of the new mine aims to have 1 million tonnes per year of ore with a grade of 1.11% lithia (5,160 tonnes/y of lithium) produced from an open pit mine which will commence in 2012 (Canada Lithium, 2010). The mine will produce 19,200 tonnes of lithium carbonate per year (3,610 tonnes of lithium). The first stage is aimed at producing 15 million tonnes of ore over a 15 year mine life, and to increase the mine life to 30 years and extract 29-30 million tonnes of ore (Canada Lithium, 2010). The deposit will be mined to a depth of 150 m, and a decision to extend the depth will be made in 2011 (Canada Lithium, 2010). A side view of the deposit is shown if Figure G.3 and the proposed open pit mine is shown in Figure G.4.

G.1.3.2. *Reserves/Resources.* Stone and Selway (2009) show historic resource estimates of the La Corne deposit as shown in Table G.3.

TABLE G.2. The analysis of spodumene concentrate at La Corne (Stone and Selway, 2009)

Substance	Ore
Li_2O	5.86
Na_2O	2.98
K_2O	0.79
Al_2O_3	25.34
SiO_2	64.92
$Fe_2O_3 + TiO_2$	0.3
CaO	0.23
MgO	0.029
Mn	0.08
Total	100.529

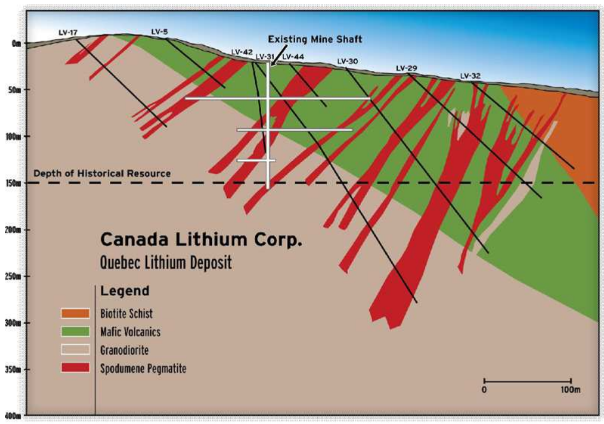


FIGURE G.3. The side view of the La Corne deposit (Canada Lithium, 2010)

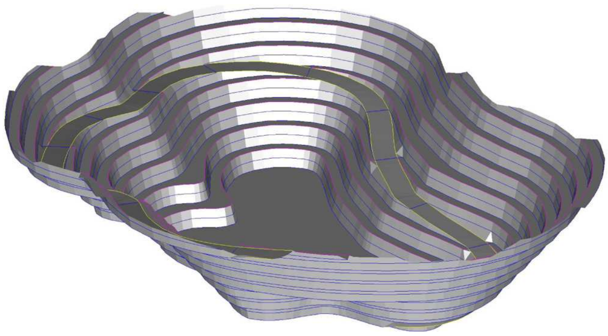


FIGURE G.4. The proposed open pit design for the La Corne deposit (Canada Lithium, 2010)

Wietelmann and Bauer (2000) stated that 0.1 million tonnes of lithium is recoverable and including potential reserves the estimate becomes 0.2 million tonnes of lithium. Garrett (2004) states that the reserves are 15 - 20 million tonnes of ore at 0.56% lithium (84,000-112,000 tonnes of lithium). Mineral Zone (2005) states the proved reserves are 20 million tonnes of spodumene

TABLE G.3. Historic resource estimate for La Corne (Stone and Selway, 2009)

Year	Company	Ore Tonnes	Grade (Li_2O)	Lithium Tonnes
1946	Nephelline Products & Great Lakes Carbon	280,502	5.86	7,643
1954	QLC	2,050,238	1.11	10,582
1955	QLC	13,607,775	1.2	75,931
1955	QLC	18,143,700	1.2	101,242
1974	SMG	15,736,938	1.14	83,422
1977	SMG	15,736,938	1.14	83,422

at 1.15% Lithia (0.53% lithium, 106,000 tonnes of lithium). Evans (2008a) states that the reserves are 90,000 tonnes of lithium.

Canada Lithium (2010) stated the measure and indicated resources are 31.6 million tonnes of ore at 1.11% lithia (0.52% lithium, 164,320 tonnes of lithium). The inferred resources are a further 38.9 million tonnes of ore at 1.12% lithia (0.52% lithium, 202,280 tonnes of lithium) (Canada Lithium, 2010). The resources of Canada Lithium (2010) are shown in Table G.4.

TABLE G.4. Estimated resources for La Corne (Canada Lithium, 2010)

Category	Ore (Mt)	Li_2O (%)	Lithium (kt)
Measured	6.896	1.1	35.3
Indicated	24.74	1.11	127.7
Sub Total	31.636	1.11	163.3
Inferred	38.94	1.12	202.8
Total	70.576		366.1

G.1.4. La Motte, Quebec.

G.1.4.1. *General.* La Motte is a spodumene deposit located in Abitibi region, Quebec near La Corne (Garrett, 2004). Glen Eagle Resources Inc. recently bought the property and intend to conduct exploratory drilling (Marketwire, 2010). Garrett (2004) states that the deposit is amenable to surface mining.

G.1.4.2. *Reserves/Resources.* Kunasz (2006) estimated reserves are 4.55 million tonnes of ore at 1.07% lithia (0.5% lithium) (∼23,000 tonnes of lithium) with additional 2.5 million tonnes of ore (resources? reserves?) below 100 m. Garrett (2004) states that this ore has a grade of >1.16% lithium hence around 29,000 tonnes of lithium. Evans (2008a) restates Kunasz (2006) value of 23,000 tonnes of lithium present.

G.1.5. Separation rapids, Ontario.

G.1.5.1. *General.* Separation rapids is in Ontario, and is roughly 200 km East of Winnipeg. There are two major deposits at Separation rapids, the Big Whopper, which is owned by Avalon Ventures and the Big Mack which is owned by Pacific Iron Ore Corporation (previously Emerald Fields Resources) as well as resources at Champion bear (Marko's) and Gossan. Separation Rapids is primarily a petalite deposit with lepidolite (Garrett, 2004).

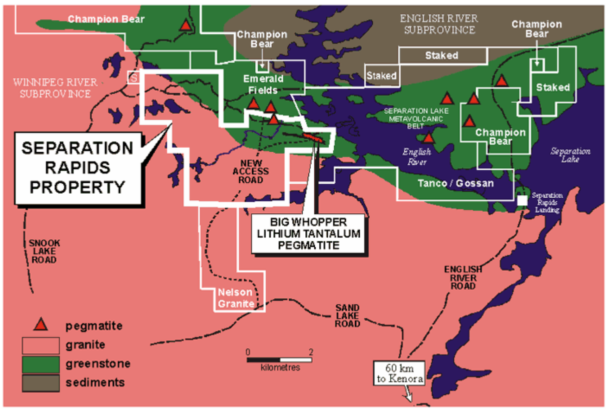


FIGURE G.5. Aerial view of the Separation Rapids deposit (Ventures, 2010a)

G.1.5.2. *Big Mack.* Big Mack has 18,200 hectares and only a small area has been drilled (Kunasz, 2006). The deposit is mostly petalite, but contains some spodumene and other minerals (Garrett, 2004). Pacific Iron (2008) state the ore has a grade of ∼30.5% petalite hence the grade is approximately 0.7% lithium (30.5% petalite, 4.9% lithia in petalite, 46.5% lithium in lithia). The deposit has a beryl and petalite "swarm" which is 30x200 m in area is and has an unknown depth (Garrett, 2004). It is aimed that the mining capacity will be 15,000 tonnes per year of petalite concentration (Kunasz, 2006).

Garrett (2004) stated that Big Mack had initial ore reserves of more than 300,000 tonnes of petalite. Kunasz (2006) reiterates that the ore reserve estimate of 300,000 tonnes of petalite for Big Mack but adds that only a small area has been drilled and the estimate is very conservative. Pacific Iron (2008) state the inferred resources are 550,000 tonnes of ore and hence the contained lithium would be 3,800 tonnes (caution, Pacific Iron (2008) claim 8,219.75 tonnes of lithium, but this is a believed to be a mistake and should by lithia).

G.1.5.3. *Big Whopper.* The area is 1350 m long and 160 m wide with an unknown depth (Garrett, 2004). According to Garrett (2004) the ore grade at Big Whopper is 1.33% lithia (0.62% lithium) and contains very little iron. Ventures (2010a) states the grade is 1.34% lithia, (0.62% lithium). The ore contains on average 37% petalite, and the petalite has a grade of 4.74% lithia (2.2% lithium) (Garrett, 2004). Pearse and Taylor (2001) claim that the ore has 25% petalite. Avalon Ventures (2007) stated they were looking to increase the marketing to ceramic and glass manufacturers. Ventures (2010b) stated that it is permitted to commence production once a market has been established. An aerial and side view of the Big Whopper deposit is shown in Figure G.6 and G.7.

Garrett (2004) stated that Big Whopper has reserves of 11.6 million tonnes of ore at 0.62% lithium (72,000 tonnes of lithium) and that 3.2 (million?) tonnes of ore (19,840 tonnes of lithium) is amenable to open pit mining. Ventures (2010a) states that the 43-101 compliant indicated

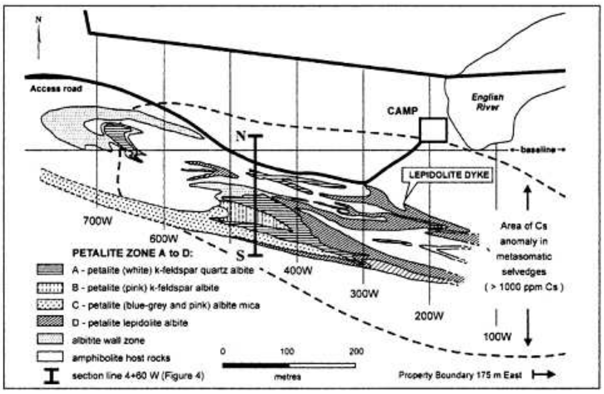


FIGURE G.6. Aerial view of the Big Whopper (Garrett, 2004)

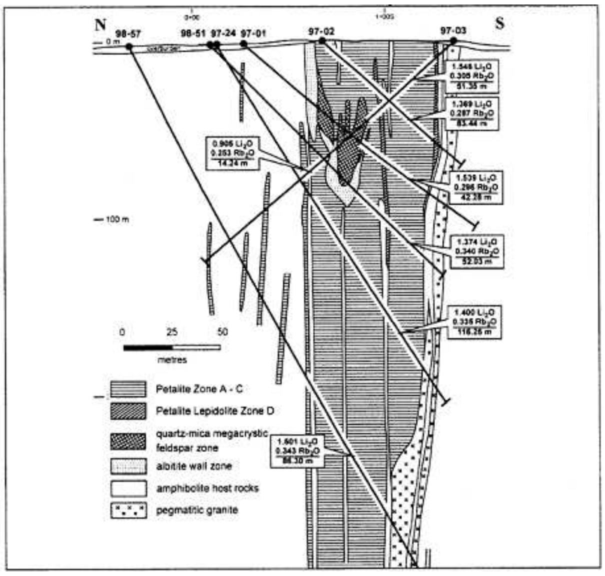


FIGURE G.7. Side view of the Big Whopper (Garrett, 2004)

petalite resource is 8.9 million tonnes and 2.7 million tonnes is inferred at a grade of 1.34% lithia (0.62% lithium) (55,180 tonnes of lithium indicated and 16,740 tonnes of lithium inferred). A pre-feasibility study indicates that an open pit design could have 7.72 million tonnes of ore reserves at 1.4% lithia (50,180 tonnes of lithium reserves and a grade of 0.65% lithium) (Ventures, 2010a).

G.1.5.4. *Marko's/Champion Bear.* The Marko's deposit is located 5 km east of the Big Whopper, and is a petalite deposit (Bear, 2010). The deposit contains up to 3.76% lithia (1.75% lithium) (Bear, 2010).

G.1.5.5. *Gossan.* Gossan Resources (2008) states that the Gossan property has an area of 432 hectares. Gossan Resources (2009) states that a 50 - 100m wide zone has been identified with lithium concentrations ranging from 0.5 - 1.42% lithium. A grab sample measured 0.8% lithium, and others 0.5 and 0.95% lithium (Gossan Resources, 2009).

G.1.5.6. *Reserves/Resources.* Evans (2008a) estimates that Separation Rapids holds 56,000 tonnes of lithium.

G.2. Oil brines

G.2.1. Fox Creek, Alberta.

G.2.1.1. *General.* Channel Resources are testing the lithium, potassium, boron and bromine brines from the oil and gas region Channel Resources (2010). The aquifers cover an area of 3980 km^2 (Channel Resources, 2010). The deposit is split into two components Beaverhill lake (aquifer, also known as Swan Hills formation) and Woodbend aquifer (or Leduc formation). Beaverhill lake is located at a depth of 3,200 m below the surface (Dufresne, 2009). The lithium concentration is 0.01 - 0.57 g/L for the southern Woodbend aquifer, 0.034 - 0.34 g/L for the northern Woodbend aquifer and 0.011 - 0.918 g/L for Beaverhill Lake (aquifer). Based on the brine analysis (Table G.6) from Dufresne (2009) it is estimated that the Mg:Li ratio is approximately 10:1.

TABLE G.5. Analysis of the Fox Creek oil field brine (Channel Resources, 2010)

	Units	Beaverhill Lake	Woodbend
Thickness	m	46	25
Porosity	ave %	7	6
Permeability	millidarcies	43	20

G.2.1.2. *Resources/reserves.* The resources are estimated at 515,000 tonnes of lithium, and are not compliant with 43-101 (Channel Resources, 2010). Gruber and Medina (2010) stated that the full report of Clarke and Harben (2009) indicated resources are 589,000 tonnes of lithium.

TABLE G.6. Detailed analysis of samples from the Fox Creek oil field brine (Dufresne, 2009)

Element	Unit	Leduc	Swan Hills	Leduc	Swan Hills
Li	mg/L or ppm	130	130	120	115
Na	mg/L or ppm	43200	54000	42400	39800
K	mg/L or ppm	7500	5100	5000	4300
Mg	mg/L or ppm	1610	2010	979	1630
Ca	mg/L or ppm	18000	15900	27500	13600
Sr	mg/L or ppm	725	630	615	
Ba	mg/L or ppm	5.7	19	4.7	1.7
Cu	mg/L or ppm		0.49	0.57	0.27
Zn	mg/L or ppm		5.9		1.9
Pb	mg/L or ppm	8.5	3.3	4	10
Ag	mg/L or ppm		1.3	1.5	0.92
Fe	mg/L or ppm		0.85	0.89	0.36
Mn	mg/L or ppm	14	14	0.38	9
V	mg/L or ppm		0.8	0.9	0.28
B	mg/L or ppm	2709	260	180	190
PO_4	mg/L or ppm	76	24	23	16
NH_3	mg/L or ppm	558	637	551	381
SiO_2	mg/L or ppm	54	43	88	19
F	mg/L or ppm	6.7	6.2		4.7
Cl	mg/L or ppm	117000	125100	123700	94160
Br	mg/L or ppm	430	436	317	329
I	mg/L or ppm	14	18	18	5
SO_4	mg/L or ppm	389	155	239	778
HCO_3	mg/L or ppm	365	232	1110	316
Salinity	mg/L	191630	205945	203703	156567
pH		7.15	6.76	8.1	7.34

APPENDIX H

Chile

H.1. Brines

H.1.1. Atacama.

H.1.1.1. *General.* Two companies, SCL and SQM extract lithium from the Salar de Atacama and production began in 1984 (Evans, 2008a). SQM was previously Minsal, and Chemetall owns SCL. The Salar de Atacama has a high lithium concentration, that is generally quoted at 0.15% lithium (Wietelmann and Bauer, 2000; Pavlovic and Fowler, 2004; Yaksic and Tilton, 2009), however Kunasz (2006) and Evans (2008b) estimate 0.14% and Anstett et al. (1990) estimates 0.125%. The Mg:Li ratio is a high at 6.4 (Pavlovic and Fowler, 2004; Yaksic and Tilton, 2009). The Salar is located 2,300 m above sea level (Kunasz, 2006). The evaporation rate is usually quoted at 3,600 - 3,700 mm/y (Pavlovic and Fowler, 2004; Yaksic and Tilton, 2009) however Harben and Edwards (1997) indicates it is 3300 mm/y and Garrett (2004) state it is 3200 mm/y (3000-3300 mm/y). The surface area of the salar is 3000 km^2 and the nucleus is 1100 km^2 (Kunasz, 2006). The lithium concentration for the Salar is between 1000 and 7000 ppm of lithium (Kunasz, 2006). SQM has a lithium carbonate capacity of 23,000 tonnes per year (Kunasz, 2006), or 28,000 tonnes per year (Pavlovic and Fowler, 2004). SCL has a production capacity of 14,500 tonnes per year of lithium carbonate (Pavlovic and Fowler, 2004). Moores (2009a) stated that production of lithium currently uses 65% of the potable water in the area. The density of the brine is 1.223 g/mL (Pavlovic and Fowler, 2004) or 1.227 g/mL (Garrett, 2004). Tables H.1 and H.2 show the brine analysis for the Atacama, and Figure H.1 has the concentration plots.

TABLE H.1. Brine Analysis for the Salar de Atacama (Garrett, 2004)

	Original brine	To Sylvinite pond	To Sulfate pond	From Carnallite pond
Cl	192.0	205.0	195.0	292.0
SO_4	23.3	45.0	88.0	23.0
B	0.77	1.61	3.15	8.74
Na	93.2	72.0	40.0	4.0
Mg	12.3	23.7	46.0	92.0
K	22.0	46.8	37.0	4.0
Li	1.96	3.66	7.07	8.9
H_2O	873	856	860	867
Density	1.227	1.258	1.284	1.323

TABLE H.2. More Brine Analysis from the Salar de Atacama in wt.% (Garrett, 2004; Pavlovic and Fowler, 2004; Wietelmann and Bauer, 2000)

	Ullmanns 2000	Pavlovic 2004[c]	Minsal[d]	Garrett (1998)	CORFO (1981)	Vergara-Edwards and Parada-Frederick (1983)[e]	Brown and Beckerman (1990)[a] Brine	Brown and Beckerman (1990)[a] Product	Orrego et al. (1994)[b] Product
Na	7.5	7.6	6.5	9.1	8	7.6	7.17	770[f]	570[f]
K	1.8	1.850	3.13	2.36	1.84	1.79	1.85	190[f]	160[f]
Mg	0.96	0.960	1.3	0.965	0.93	1	0.96	1.29	1.92
Li	0.15	0.150	2420[f]	1570[f]	1500[f]	1600[f]	1500[f]	63000[f]	60000[f]
Ca	0.03	0.031	530[f]	450[f]	300[f]	245[f]	310[f]	530[f]	
Cl	16.0	16.040	17.3	18.95	15.90	15.66	16.04	34.46	35.1
SO_4	1.78	1.650	0.8	1.59	1.70	1.9	1.46	166[f]	220[f]
B		0.064	556[f]	440[f]	600[f]	685[f]	400[f]	7300[f]	6270[f]
Br	trace						50[f]		
HCO_3			600[f]	230[f]					
Density		1.223	1.227			1.226		1.25	1.252
pH								6.5	

[a]Patent assigned to Foote
[b]Final solar pond brine
[c]From Pavlovic and Fowler (2004)
[d]Estimated
[e]Km-20 brine
[f]ppm

SCL has 137km^2 (Gruber and Medina, 2010) and a lithium content of 1900 ppm lithium (Harben and Edwards, 1997). At SCL, the initial brine concentration is 0.2% lithium, and the final concentration is 6% (Chemetall, 2009).

SQM commenced operating in the Salar de Atacama in 1995 (then Minsal) (Harben and Edwards, 1997). The initial brine concentration is 3400 ppm lithium (Garrett, 2004). Gruber and Medina (2010) stated that SQM has a claimed surface area of 820km^2. Once the KCl is removed the brine contains 1% lithium (Harben and Edwards, 1997). The brine is then cooked to a concentration of 6% lithium and is then trucked 250 km to be processed (Harben and Edwards, 1997).

Harben and Edwards (1997) stated that the top 20-25 meters of the salt have high porosity and permeability, and below that the salt is recrystallised. Garrett (2004) stated that the porosity for the upper 25m has an average of 18% and that the porosity decreases to near zero below a depth of 35-40m. Gruber and Medina (2010) states the maximum depth of the Salar is 360m. Lithium concentrations average 200-300 ppm in marginal zones, 500-1600 ppm in intermediate zones and 1510-6400 ppm in the halite zone (Harben and Edwards, 1997). SQM exploits an average concentration of 3,400 ppm and SCL 1,900 ppm (Harben and Edwards, 1997). Garrett (2004) stated that the concentration is 1000 - 4000 ppm and averages 1500 ppm lithium. The lithium concentration map is shown in Figure H.2. Anstett et al. (1990) indicated that Chile has a production capacity of 1360 tonnes of lithium.

H.1.1.2. *Reserves/Resources.* The resources and reserves are heavily disputed.

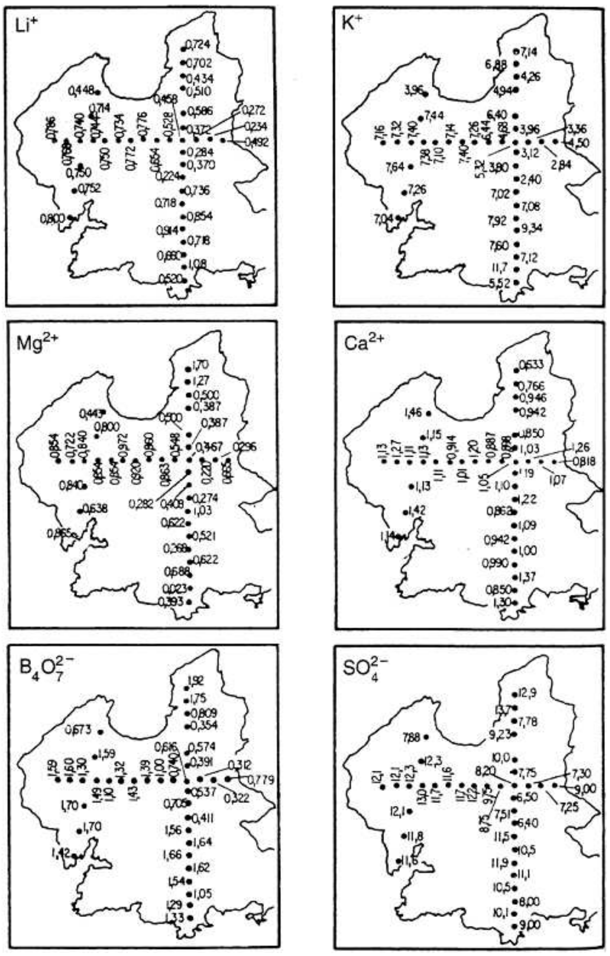


FIGURE H.1. Concentration plot of key ions for Atacama (Garrett, 2004)

Kesler (1978) first indicated that Salar de Atacama had 1.29 million tonnes of lithium with a further 3 million tonnes of lithium resources at a grade of 0.135 wt.%. Anstett et al. (1990) indicated that the Salar de Atacama had economic in-situ resources of 201,000 tonnes of lithium, 1,099,000 tonnes of marginally economic in-situ resources of lithium, 325,000 tonnes of sub economic in-situ resources, and 2,675,000 tonnes of in-situ lithium resources in extensions of known deposits. Hence Anstett et al. (1990) indicates total resources at 4.3 million tonnes of lithium. Harben and Edwards (1997) estimated the lithium reserves for Salar de Atacama at 2,200 million tonnes[1]. SQM has rights to exploit 1586 km^2 of the Salar, up to 40 meters of depth, which translates to 1.8 million tonnes of lithium (resources?) (Harben and Edwards, 1997).

Wietelmann and Bauer (2000) indicated the Salar de Atacama has 0.8 million tonnes of recoverable lithium and more than 1.1 million tonnes of lithium resources in place. Garrett (2004) places the reserves at 3 - 4.6 million tonnes of lithium, and that SQM area contains 1.7-1.8 million tonnes of lithium. Kunasz (2006) presumably following (Anstett et al., 1990), stated that indicated resources of the salar are 4.3 million tonnes of lithium. Tahil (2007) indicated the reserves are 1.5 million tonnes of lithium and the reserve base is 3 million tonnes of lithium, using Evans (1978) value of 2.2 million tonnes of resources to a depth of 60 m and a 50% recovery.

[1]believed to be a typo in Harben and Edwards (1997) and probably should read 2.2 million tonnes

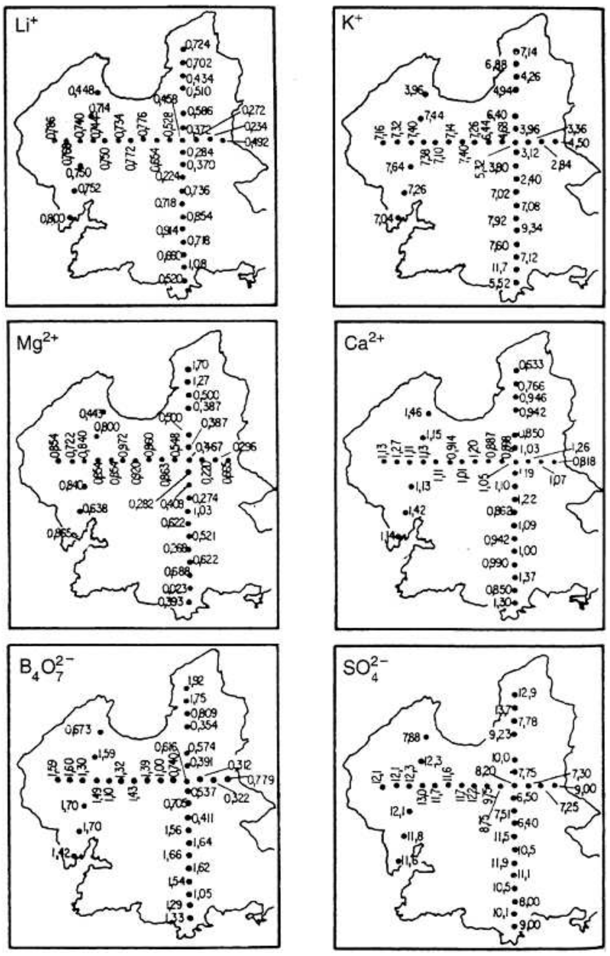


FIGURE H.2. Lithium content for the Salar de Atacama (Kunasz, 2006)

Evans (2008a) indicates that SCL had reserves of 500,000 tonnes of lithium prior to production. SQM initially stated reserves of 1.8 million tonnes of lithium, based on an area of 790 km^2, depth of 40 m and average grade of 0.18% lithium (Evans, 2008a). SQM later revised the reserves to 6 million tonnes of lithium to a depth of 200m (Evans, 2008a). Evans (2008a) estimates that the buffer zone between the two companies licensed areas contains 400,000 tonnes of lithium, hence a total reserve of 6.9 million tonnes of lithium. Evans (2008a) further states that SCL has 'reserves' of 1.29 million tonnes of lithium in detailed drilling and 3 million tonnes inferred (Evans (2008a) use of the term reserves is believed to mean resources).

Tahil (2008) argues that only the top 30 m of the deposit is valid, and assumes a porosity of 4.4% to obtain a URR for the Salar at 1.1 million tonnes of lithium. Evans (2008b), points out numerous errors in Tahil (2008), and states that 500,000 tonnes of lithium to SCL was wrong, and should have been 600,000 tonnes lithium. Evans (2008b) further states that the Salar contains 7 million tonnes of lithium (reserves or resources?).

Chemetall (2009) indicated the Salar de Atacama resources are 31.5 million tonnes of lithium carbonate equivalent ($\sim$5.9 million tonnes of lithium). Yaksic and Tilton (2009) indicate the Salar de Atacama has 35.7 million tonnes of lithium resources, of which 7 million tonnes are lithium reserves. Mineral Commodity Summary (var) had consistently estimated 3 million tonnes of reserves for Chile, but recently revised this to 7.5 million tonnes. Clarke and Harben (2009) stated the lithium reserves (for Chile) are 7.52 million tonnes of lithium. Gruber and Medina (2010) estimate the lithium resource is greater than 6.3 million tonnes of lithium.

H.1.2. Maricunga. Yaksic and Tilton (2009) indicate reserves are 220,000 tonnes of lithium. The deposit has a lithium grade of 0.092% lithium, an evaporation rate of 2,600 mm/y and a Mg:Li ratio of 8 (Yaksic and Tilton, 2009).

APPENDIX I

China

Prior to early 2000's all of China's production was from rock sources (Evans, 2008a). Tahil (2007) believes that China has 1.1 million tonnes of lithium reserves and 2.7 million tonnes of lithium reserve base.

I.1. Brines

I.1.1. Lake Zhabuye.

I.1.1.1. *General.* Pavlovic and Fowler (2004) states that the Zhabuye salt lake has a lithium content of 0.12%, although Yaksic and Tilton (2009) quotes it at 0.05-0.1%. Zhabuye has a very low Mg:Li ratio of 0.001 and an evaporation rate of 2,300 mm per year (Yaksic and Tilton, 2009). Gruber and Medina (2010) stated the surface area of the lake is 145km^2 for South Zhabuye and 98km^2 for North Zhabuye, and the average depth is 0.7m.

Tahil (2007) states that the lake is 4422 meters above sea level. Lake Zabuye has a lithium content of 700-1000 ppm, although it is also stated as 800 ppm (Kunasz, 2006). Garrett (2004) and Tahil (2008) states the lithium content is 500-1000 ppm. The density of the brine is 1.297 g/mL (King, 2010). The analysis of the brine is shown in Tables I.1 and I.2.

TABLE I.1. Solar Evaporation of Zhabuye brine (g/L) (Garrett, 2004)

No.	ρ^a	pH	Tot. Salts	K	Na	Li	Rb	Cs	CO_3	SO_4	Cl	Br	I	B	ratio^b
1	1.3047	10.86	428.56	50.00	139.11	0.87	0	0.034	42.13	28.52	160.54	0.965	0.0013	5.9	1.0
2	1.3226	-	433.01	55.15	142.44	1.08	0	0.043	40.03	29.65	156.12	1.04	0.0024	6.81	1.25
3	1.3333	10.83	442.58	59.00	142.44	1.26	0.090	0.054	52.33	25.56	151.67	1.29	0.0030	8.40	1.52
4	1.3573	10.38	462.82	65.10	146.15	1.44	0.140	0.066	70.33	23.09	144.55	1.49	0.0021	9.87	1.67
5	1.3630	10.67	465.13	62.50	146.15	1.48	0.140	0.069	80.20	22.19	139.81	1.78	0.0021	10.81	1.76
6	1.3703	10.75	469.82	62.50	155.06	1.50	0.180	0.081	82.33	20.99	132.09	2.07	0.0028	13.01	2.18
7	1.3762	-	472.54	62.50	158.77	1.51	0.180	0.085	88.78	20.21	126.16	2.07	0.0011	13.25	2.23
8	1.3880	10.92	456.88	59.00	162.25	1.63	0.240	0.100	76.93	19.76	121.41	2.34	0.0024	15.22	2.73
9	1.3851	10.98	481.45	59.00	156.91	1.65	0.240	0.100	105.02	18.54	121.69	2.41	0.0025	15.89	2.77
10	1.3987	11.11	472.74	55.15	160.18	1.50	0.240	0.104	97.34	19.55	118.15	2.56	0.0021	16.66	2.85
11	1.4168	11.36	491.73	55.15	173.60	1.82	0.360	0.113	116.35	19.86	107.17	3.33	0.0026	15.97	3.66
12	1.4120	11.22	488.63	56.00	173.61	1.62	0.480	0.180	111.44	18.11	106.93	4.92	0.0038	15.34	5.31
13	1.4155	11.12	505.92	63.00	173.61	1.56	0.720	0.225	116.30	19.92	108.47	5.84	0.0064	16.27	7.31
14	1.4214	11.22	497.44	56.00	181.02	1.64	0.880	0.290	106.82	20.02	105.39	6.78	0.0071	18.59	9.16
15	1.4367	11.08	507.76	56.00	181.02	1.46	1.240	0.450	113.66	19.76	103.73	9.35	0.0074	22.08	13.51
16	1.4409	11.13	524.24	93.35	178.13	1.26	1.800	0.633	107.02	19.76	99.09	13.37	0.0144	22.08	19.31

[a]density
[b]Concentration ratio

The planned capacity is 5,000 tonnes per year of lithium carbonate (940 tonnes per year of lithium) (Kunasz, 2006). Tahil (2007) believes ultimate capacity will be 20,000 tonnes per year of lithium carbonate (3760 tonnes per year lithium).

TABLE I.2. Solar Evaporation of Zhabuye brine (wt.%) (Wietelmann and Bauer, 2000)

Basin	Na	K	Mg	Li	SO_4	Cl	Br
Zhabuye	14.17	3.96	0.001	0.12	4.35	15.63	0.6

I.1.1.2. *Reserves/Resources.* Garrett (2004) states the reserves are 1 million tonnes of lithium. Tahil (2007) states that Zhabuye salt lake has 4 Mt of recoverable lithium carbonate (752,000 tonnes of lithium). Evans (2008a) states that Zhabuye reserves are claimed to be 1,530,000 tonnes of lithium but states that others claim it is much lower. Tahil (2008) states that Zhabuye has 1 million tonnes of lithium resources. Yaksic and Tilton (2009) stated that Zhabuye has reserves of 1.53 million tonnes of lithium.

I.1.2. Qinghai - Qaidam Basin (including Taijinaier).

I.1.2.1. *General.* Qaidam Basin contains 37 lakes, with 28 being salt lakes at an elevation of ∼2,790m (Gruber and Medina, 2010). Gruber and Medina (2010) assumed that Taijinar is the same lake as Taijinaier and that both describe Xitai and Dongtai lakes. If it can be assumed that Taijiner is also a spelling verion of Taijinaier, then Kunasz (2006) has the lithium content at 350-400 ppm. CITIC is beginning lithium production at Taijinaier (Evans, 2008a). Tahil (2007) states that CITIC Guoan has a capacity of 35,000 tonnes per year of lithium carbonate (6,580 tonnes of lithium), and Tahil (2008) states that Qaidam basin a 500 tonnes per year pilot plant (lithium chloride and lithium carbonate) started in 2004. Qinghai has a lithium content of 100 ppm and the Mg:Li ratio is very high (Kunasz, 2006). Taijinaier has a lithium grade of 0.03%, a Mg:Li ratio of 34 and an evaporation rate of 3560 mm per year (Yaksic and Tilton, 2009). Gruber and Medina (2010) stated the lithium concentrations for various lakes at: 22.91 mg/L at Dongtai, 29.03 mg/L at Xitai. Evans (2008a) states the Mg:Li ratio is high at between 40 and 60. The aim is to produce 100 tonnes per year of lithium chloride (Kunasz, 2006). Analysis of the basin is shown in Table I.3.

TABLE I.3. Analysis of the Qaidam basin brines in wt.% (Garrett, 2004; Wietelmann and Bauer, 2000)

	ρ^a	pH	Tot. Salts	Na	K	Mg	Ca	Li	Cl	SO_4	HCO_3	CO_3	B_2O_3	Br
Da Qaidam														
Intercryst.	1.234	7.30	25.05	5.63	0.44	2.02	0.02	310^b	13.42	3.41	0.06	0.02	0.2	58^b
Surface	1.240	7.40	25.68	7.77	0.36	1.17	0.03	182^b	14.16	2.04	0.21		0.26	80^b
Kiao Qaidam														
Surface	1.203	21.76	5.43	0.13	0.39	0.08	38^b	12.14^b	3.57	0.004		0.19	16.6^b	
Mahai														
Intercryst.	1.208		22.38	8.08	0.16	0.96	0.07	51^b	10.84	2.33			434^b	
Qinghai Lake	1.133		14.23	3.93	0.16	0.79	0.01	0.84^b	5.79	2.35	0.68	0.52	15^b	1.5^b
Dachaidan[c]				10.6	0.4	1.3	0.4	0.02	18.7	2.25				7.0

[a]density
[b]ppm
[c]Wietelmann and Bauer (2000)

I.1.2.2. *Reserves/Resources.* The Qinghai Lake is estimated to have 1 million tonnes of lithium reserves (Garrett, 2004). The Qaidam basin has resources of nearly 14 million tonnes of lithium chloride (2.3 million tonnes of lithium) (Kunasz, 2006). Tahil (2007) states that Taijinaier Salt Lake has 1.4 Mt of recoverable lithium carbonate (260,000 tonnes of lithium). Evans (2008a) estimates that Taijanier lakes reserves are 940,000 tonnes of lithium and that the whole Qaidam Basin, may have 3.3 million tonnes of lithium. Tahil (2008) claims Qinghai contains 1 million tonnes of lithium resources. Yaksic and Tilton (2009) stated that the Qaidam basin has 2.02 million tonnes of lithium resources (Including Taijinaier), and that Taijinaier has 260,000 tonnes of lithium reserves. However Yaksic and Tilton (2009) states that Qaidam Basin has 13.92 Mt of lithium chloride which is 2.28 Mt of lithium, hence it should say excluding Taijinaier, not including. Salt Lake Group (2009) states that the lithium chloride reserves in Chaerhan is 8 million tonnes, (1.3 Mt of lithium). Gruber and Medina (2010) stated that the full report from Clarke and Harben (2009) has a reserve of 3.13 Mt for Qaidam. Gruber and Medina (2010) assumed the resources estimate from Yaksic and Tilton (2009). Sichuan Sheng Ni Kei Guo Run Xin Cai Liao Co. Ltd. (ND) stated that Taijinaier is expected to have lithium reserves of 3.37 Mt of lithium.

I.1.3. DXC.

I.1.3.1. *General.* Sterling Ventures is working to produce lithium at DXC lake. The lake is 55.53 km^2 in area and has an average depth of 7.58 m (Sterling Group, 2010); maximum depth is 14m (Sterling Group, 2009). DXC is stated as having a grade of 0.04-0.05% lithium (Yaksic and Tilton, 2009). Sterling Group (2010) state the lithium grade is 0.4 g/L lithium and Tribe (2006) stated it is 0.43g/L. The evaporation rate is 2,300 mm per year and the Mg:Li ratio is 0.22 (Yaksic and Tilton, 2009; Sterling Group, 2010). The average rainfall is 150mm a year (Sterling Group, 2010). The salt lake is at an altitude of 4475 m above sea level (Tahil, 2007). Tahil (2007) stated that DXC need to concentrate the brine to 6% lithium by evaporation and then tanker the brine 400 miles away to the nearest railway facility, or to transport soda ash to the brine. The brine is basic with a pH of 8.9 - 9.7 (Sterling Group, 2010).

Sterling is developing a 5,000 tonnes per year (lithium? Lithium carbonate?) plant at DXC (Tahil, 2007). A contour map of the lithium chloride concentration is shown in Figure I.1 and the brine analysis is shown in Table I.4.

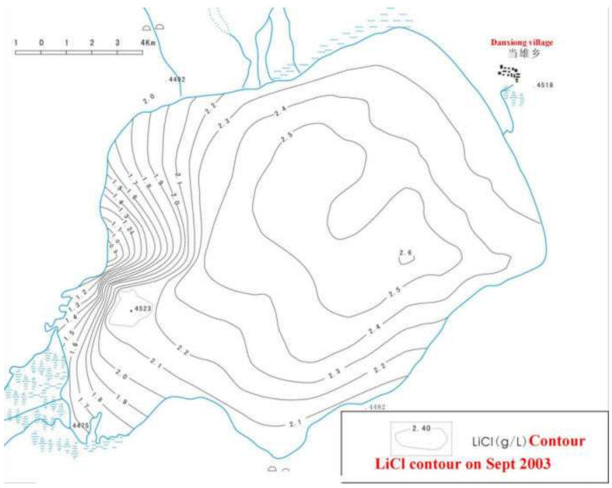


FIGURE I.1. Lithium chloride content for DXC (Sterling Group, 2010)

TABLE I.4. Analysis of the DXC brine in g/L (Sterling Group, 2010)

Date	Na	K	Ca	Mg	Li	Rb	Cs	Br	As	Cr	SO_4	HCO_3	CO_3	B_2O_3	F	Cl
July	65	11.9	0	0.09	0.43	0.0216	<0.001	0.247	0.0197	87.4	6.87	2.8	12.5	3.2		87.4
March	61.3	13.2	3.17	0.09	0.4	0.0222	0.00038	0.2878		86.3	6.62	1.48	12.9	3	0.00914	86.3
September	59.5	11		0.13	0.38	0.0188		0.2737		83.8	6.11	2.23	11.6	2.936	0.00775	83.7

I.1.3.2. *Reserves/Resources.* Tribe (2006) calculates the reserves of lithium chloride at 1,036,100 tonnes (170,000 tonnes of lithium). Tahil (2007) stated that 0.4 Mt of lithium carbonate is recoverable in DXC (75,200 tonnes of lithium). Evans (2008a) stated that Sterling group ventures, intend to develop 170,000 tonnes of lithium at DXC. Tahil (2008) claims DXC has resources of 1 Mt of LiCl (160,000 tonnes lithium). Yaksic and Tilton (2009) stated that DXC has 140,600 tonnes of lithium reserves. Sterling Group (2010) stated the reserves are 748,490 tonnes of lithium carbonate (140,700 tonnes of lithium). Gruber and Medina (2010) estimated that DXC has 181,300 tonnes of lithium resources.

I.2. Ore

Anstett et al. (1990) estimated that China has 70,000 tonnes of economically recoverable resources of lithium, and that China has a production capacity of 700 tonnes of lithium. Garrett (2004) stated China has 500,000 tonnes of lithium reserves.

I.2.1. Jaijika.

I.2.1.1. *General.* Sichuan Minerals Industry owns the lithium at Jaijika (Evans, 2008a). Sterling Group initially acquired a 75% interest in the Jiajika project however this partnership was terminated (Sterling Group, 2009). The deposit is an 88km^2 spodumene deposit (Sterling Group, 2009), although Gruber and Medina (2010) stated it is 62km^2 in area. Jaijika has a lithium grade of 0.59% (Yaksic and Tilton, 2009), although Gruber and Medina (2010) stated it was 0.65%. It aims to have an initial capacity of 240,000 tonnes per year (presumed ore) (Kunasz, 2006; Sterling Group, 2009). It aims to produce 47,320 tonnes per year of 6.09% lithia concentrate (2.8% lithium) (1,325 tonnes per year of lithium) Kunasz (2006).

I.2.1.2. *Reserves/Resources.* Kunasz (2006) stated the reserves are 1.03 million tonnes of ore at 1.28% lithia (0.6% lithium) (6,180 tonnes of lithium). Evans (2008a) stated Jaijika has 480,000 tonnes of lithium (resources?). Yaksic and Tilton (2009) stated the resources are 450,000 tonnes of lithium. Gruber and Medina (2010) estimated the resources to be 204,000 tonnes of lithium.

I.2.2. Gajika. Gajika is a spodumene ore deposit (BusinessPatrol, ND). The deposit is estimated to have 1.266 Mt of lithia reserves ($\sim$590,000 tonnes of lithium) (BusinessPatrol, ND). Yaksic and Tilton (2009) stated the resources at Gajika are 560,000 tonnes of lithium.

I.2.3. Yichun. Garrett (2004) stated that in 1998 Yichun held 90% of the country's recoverable lithium reserves and that Lepidolite is mined in an open pit. The grade is believed to be 4–4.5% lithia (1.86–2.1% llithium) (Lei, 2010). The proven reserves are stated as being 1.1 Mt of lithia (0.51 Mt of lithium) Gruber and Medina (2010) stated that Clarke and Harben (2009) estimated the resources are 325,000 tonnes of lithium, and Gruber and Medina (2010) assumed this value was correct.

I.2.4. Maerkang. Sichuan Ni and Co owns the mine at Maerkang (Evans, 2008a). It is believed (by the author) that Sichuan Ni and Co is the same as Sichuan Sheng Ni Kei Guo Run Xin Cai Liao Co which is a sub-company of CITIC group (Sichuan Sheng Ni Kei Guo Run Xin Cai Liao Co. Ltd., ND). The ore is spodumene and the reserves are 483,000 tons of lithia (225,000 tonnes of lithium reserves) (Sichuan Sheng Ni Kei Guo Run Xin Cai Liao Co. Ltd., ND). Sichuan Ni and Co reserves are 80,000 or 225,000 tonnes of lithium (Evans, 2008a). Yaksic and Tilton (2009) stated the resources at Maerkang are 220,000 tonnes of lithium. Gruber and Medina (2010) assumed the deposit had 225,000 tonnes of lithium resources.

I.2.5. Daoxian. Gruber and Medina (2010) Stated that Sterling Group Ventures intended to develop the Daoxian lithium resource. Evans (2008a) estimated that Daoxian has 125,000 tonnes of lithium. Doutaz (2004) stated that Daoxian has 390,000 tonnes of lithia resources (181,000 tonnes of lithium resources). Doutaz (2004) stated the ore grade is 0.552% but it is unclear if this is lithia or lithium. Gruber and Medina (2010) assumed a resource of 182,000 tonnes of lithium.

I.2.6. Lushi. Evans (2008a) stated that Lushi is owned by Sterling group ventures. Doutaz (2004) stated that Lushi has 200,000 tonnes of ore at 1% lithia grade (0.47% lithium) (930 tonnes of lithium) and that there is large potential to increase the resources of lithium. The concession area is 100 km^2 and the deposit is located 800 m above sea level (Doutaz, 2004). Evans (2008a) estimated that Lushi has 9,000 tonnes of lithium.

I.2.7. Altai Mountains. Wietelmann and Bauer (2000) indicate that the Altai mountains have a spodumene reserve, with a grade of 1.5

APPENDIX J

Finland

There are four known deposits of lithium in Finland. The first is in Osterbotten, where production is anticipated to commence in 2010, the resources are 3 million tonnes of spodumene and has a lithium content of 0.43% lithium (12,900 tonnes) Nordic Mining (2008). The second deposit is the Tammela project located at Kietyonmaki/Hirvikallio. The resources are inferred to be 400,000 tonnes of spodumene at a grade of 0.47% lithium (1,880 tonnes lithium) Nortec Minerals (2010). However, Nortec Minerals (2010) also indicates Kietyonmaki has existing resources of 400,000 tonnes of ore at 0.7% lithium, and indentified resources (believed to be including existing resources) of 1 million tonnes of ore at 0.7% lithium (7,000 tonnes of lithium). Also, Nortec Minerals (2010) indicated Hirvikallio (adjacent to Kietyonmaki) has 100,000 tonnes of ore at 0.47% lithium (470 tonnes of lithium). A total of 16,000 tonnes of lithium appear to be present for the Kietyonmaki/Hirvikallio site. Nortec Minerals (2010) also has lithium deposits at the Seinajoki gold project, and Kaatiala rare earth project. The lithium at Kaatiala is lepidolite Nortec Minerals (2010). Evans (2008a) roughly estimates Finland's reserves to be 14,000 tonnes of lithium.

APPENDIX K

France

Anstett et al. (1990) indicated that uneconomic and extensions of known deposit resources are 500,000 tonnes of ore, at 0.7% lithium (3,500 tonnes of lithium).

APPENDIX L

FSU

Anstett et al. (1990) estimated the recoverable economic resources for FSU are 130,000 tonnes of lithium, and that the production capacity is 1,350 tonnes per year of lithium. Wietelmann and Bauer (2000) stated that Russia has spodumene and lepidolite at Krivoj Rog and Chita in Transbaikal. Garrett (2004) stated that Russia has 130,000 tonnes of lithium reserves and that the Tro San Zhen deposit in Kyrgyzstan has significant reserves. Kunasz (2006) stated that Russia has the Pervomaisky spodumene mine and Tahil (2008) claims this mine was shut down due to not being economic. Yaksic and Tilton (2009) states that Etykinskoe has a lithium grade of 0.23-0.79%. Evans (2008a) claims that Russia has 1 million tonnes of lithium. Yaksic and Tilton (2009) stated that Russia has 1.16 million tonnes of lithium resources. Clarke and Harben (2009) estimated that Russia had 2.48 Mt tonnes of lithium reserves. Gruber and Medina (2010) estimated Russia has 844,000 tonnes of lithium resources.

APPENDIX M

Israel/Jordan

M.1. Brines

M.1.1. Dead Sea.

M.1.1.1. *General.* The dead sea is estimated to have a lithium concentration of 11.6 ppm (Garrett, 2004). However a 30 ppm lithium concentrate is produced by recovery of potash (Garrett, 2004). The composition of the brine is shown in Table M.1.

TABLE M.1. Analysis of the Dead Sea brine in wt.% (Garrett, 2004; Pavlovic and Fowler, 2004; Wietelmann and Bauer, 2000)

	Na	K	Mg	Ca	Li	Cl	SO_4	HCO_3	B	Br	SiO_2	ρ^a
Sea	3.01	0.56	3.09	1.29	12^b	16.10	0.061	190^b	30^b	3760^b	11^b	1.198
Conc.	0.38	0.22	7.01	2.65	23^b	25.60						
Sea[c]	3.21	0.6	3.33	1.18	0.002	17.32	0.07		0.003			1.2
Sea[d]	3.0	0.6	4.0	0.3	0.002	16.0	0.05			0.4		

[a]density
[b]ppm
[c]from Pavlovic and Fowler (2004)
[d]from Wietelmann and Bauer (2000)

M.1.1.2. *Reserves/Resources.* Garrett (2004) claimed the lithium reserves are 2 million tons, but Yaksic and Tilton (2009) stated the resources are 2 million tonnes. Tahil (2008) stated the Mg:Li ratio is 2000:1. Garrett (2004) noted that lithium recovery has been attempted however the chemicals needed are very high (for 1 tonne of lithium, 73 tonnes of lime, 19,000 m^3 of water and 92 tonnes of HCl are needed). The difficulties surrounding the Dead Sea, lead Gruber and Medina (2010) to conclude the Dead Sea was "not a foreseeable resource of lithium".

APPENDIX N

Mali

Little information exists on the deposit in Bougouni, Mali. Garrett (2004) stated that it is a spodumene and amblygonite deposit, and that it was mined between 1956 and 1970 (production statistics cannot be located). The resources classified as uneconomic and extension of a known deposit is estimated at 1 million tonnes of ore (Anstett et al., 1990). The grade is disputed with Anstett et al. (1990) indicating a grade of 0.56% lithium and Yaksic and Tilton (2009) indicating 1.4%. Garrett (2004) states the reserves are 266,000 tonnes of ore at 1.4% lithium (3,724 tonnes of lithium), however Garrett (2004) also states that Mali has 26,000 tonnes of lithium reserves. Yaksic and Tilton (2009), states that Mali has 26,000 tonnes of lithium resources.

APPENDIX O

Namibia

Limited data is available on lithium in Namibia. The lithium deposit is in karibib (Kesler, 1978). The resource of 900,000 tonnes of ore (petalite, amblygonite and lepidolite) (Anstett et al., 1990). The grade is estimated at 0.93% lithium (Anstett et al., 1990).

The economic reserves in 1951 were estimated at 100,000 tonnes of ore at greater than 1.4% lithium and uneconomical and extension of known deposit resources were estimated at 900,000 tonnes of ore at a grade of 0.93% lithium (Anstett et al., 1990). Combining the data from Anstett et al. (1990) obtains a resource of 9,770 tonnes of lithium. Kesler (1978) has reserve and resource estimates shown in Table O.1. Garrett (2004) stated that Namibia has 9,800 tonnes of lithium reserves. Garrett (2004) stated that there is 1 million tonnes of lepidolite ore, and 200,000 tonnes of petalite ore. Recently Yaksic and Tilton (2009) estimated the resources to be 11,500 tonnes of lithium.

TABLE O.1. Reserves and resources for Namibia (Karibib) (Mt) (Kesler, 1978)

	Reserves		Resources
	Proved	Probable	Possible
Namibia ore	0.15	0.3	0.65
Namibia grade	1.4	1.4	1.4
Namibia Li	0.0021	0.0042	0.0091

APPENDIX P

Portugal

Information on Portugal is scarce. Garrett (2004) estimates Portugal has 10,000 tonnes of lithium reserves.

Garrett (2004) states Barroso-Alvao is a spodumene with petalite and amblygonite deposit with a grade of 0.37-0.77% lithium. Yaksic and Tilton (2009) has the grade at Barroso-Alvao at 0.37-0.77% lithium and resources of 10,000 tonnes of lithium.

Garrett (2004) and Yaksic and Tilton (2009) indicate that Covas de Barroso has a lithium content of 0.72%.

Garrett (2004) states that the Guarda area lepidolite and amblygonite deposit has been mined, and that the Goncalo deposit in Beira Alta is a lepidolite one.

APPENDIX Q

Serbia

RTZ announced a new lithium and boron mineral called Jadarite - 3 horizons, each 14 m thick, lowest zone targeted has 80–100 million tonnes at 2% lithia (850,000 tonnes lithium) and 13 million tonnes B_2O_3 (Evans, 2008a). Gruber and Medina (2010) indicated that the surface area of the deposit is $5km^2$. Gruber and Medina (2010) indicated that the ore resource is 114.6 Mt and that the average grade is 1.8% lithia (0.84% lithium) and hence a lithium resource of $\sim$0.99 Mt of lithium. Rio Tinto is planning on mining 1 Mt of ore per year (8,370 tonnes of lithium per year) (Gruber and Medina, 2010).

APPENDIX R

South Africa

Garrett (2004) stated that Noumas and Norrabees areas contain 30,000 tonnes of lithium, the deposits are spodumene.

APPENDIX S

USA

S.1. Brines

S.1.1. Silver Peak, Clayton Valley.

S.1.1.1. *General.* Clayton valley brine operations in Nevada and commenced in 1966 (Garrett, 2004) or in 1960 (Evans, 2008a) or in 1967 (TNR, 2010b). It is the only lithium producer in the United States (TNR, 2010b). Garrett (2004) stated the salt lake is 83km^2 and has an elevation of 1300m. The evaporation rate is contested, with Tahil (2008) claiming 900 mm/y, (Yaksic and Tilton, 2009) 1000 mm/y and Garrett (2004) and Harben and Edwards (1997) stating it is 1800 mm/y. Although Garrett (2004) also stated that the evaporation rate in the area is 760 - 1200 mm/y. A map of the Clayton Valley area is shown in Figure S.1 and the concentration of the brine is shown in Table S.1.

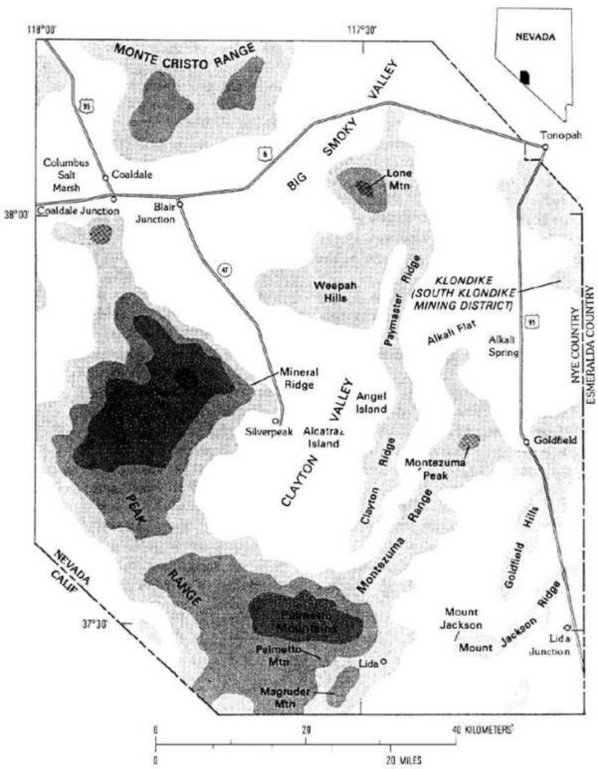


FIGURE S.1. Clayton Valley area (Garrett, 2004)

Initially the lithium concentration was 100-800 ppm lithium in the central area, and at commencement of operations in 1966 the concentration averaged 400 ppm (Garrett, 2004). Tahil (2008) agrees stating lithium concentration averaged 360 mg/L in 1966. The average brine concentration decreased to 300 ppm lithium in 1970 and was 160 ppm in 2001 (Garrett, 2004). Kunasz

TABLE S.1. Analysis of the Clayton Valley brine in wt.% (Garrett, 2004; Pavlovic and Fowler, 2004; Wietelmann and Bauer, 2000)

			Barret and O'Neill (1970)			Davis (1986)		Brown[a]		Pavlovic[b]	Ullmanns[c]
	First Well	Anon (1966)	Feed	Product	Kunasz (1974)	well	Springs	(1990)	Garrett (1996)	2004	2000
Na	8.16	7.50	6.20	7.80	6.62	6.37	9010[d]	6.20	4.69	6.2	7.5
K	1.17	1.00	0.80	4.80	0.77	0.8	892[d]	0.80	0.40	0.53	1.0
Li	678[d]	400[d]	400[d]	5000[d]	380[d]	230[d]	36[d]	200[d]	163[d]	0.023	0.02
Mg	533[d]	600[d]	400[d]	70[d]	600[d]	360[d]	51[d]	200[d]	190[d]	0.033	0.03
Ca	407[d]	500[d]	500[d]	40[d]	560[d]	450[d]	372[d]	200[d]	450[d]	0.02	0.05
Cl	13.11	11.70	10.10	16.10	9.50	10.00	13,850[d]	10.06	7.26	10.06	11.7
SO_4	1.12	0.75	0.71	2.90	1.11	0.66	545[d]	0.71	0.34	0.71	0.75
B										0.008	
Br	28[d]					31[d]		20[d]	23[d]		
ρ[e]	1.180			1.25		1.079			1.058		
pH						7.1	7.3				

[a]Brown and Beckerman
[b]Pavlovic and Fowler (2004)
[c]Wietelmann and Bauer (2000)
[d]ppm
[e]density

(1983) stated the brine concentration was 200 ppm of lithium. Anstett et al. (1990) stated the lithium grade is 0.033% lithium. Harben and Edwards (1997) stated that the lithium content is 160 ppm and that after KCl removal the brine contains 0.015% lithium, and the final concentration is 6,000 ppm lithium. By 1998 the concentration had declined to 100-300 ppm lithium (Garrett, 2004). Tahil (2007, 2008) and Yaksic and Tilton (2009) stated the lithium concentration is 0.023% lithium.

The Mg:Li ratio is consistently 1.4-1.5 in the literature with Tahil (2007) stating 1.43, Orocobre (2009) stating 1.4 and Yaksic and Tilton (2009) stating 1.5. Anstett et al. (1990) stated the production capacity at Silver Peak is 1,200 tonnes of lithium. Tahil (2007) states that production is around 9000 tonnes of lithium per year and falling. The production capacity in 1966 was 14 million pounds/y of lithium carbonate (1,200 tonnes of lithium) (Garrett, 2004).

S.1.1.2. *Reserves/Resources.* Kesler (1978) has the reserve and resources of Silver Peak shown in Table S.2. Anstett et al. (1990) stated that Silver Peak has 30,000 tonnes of economic in-situ resources, 35,000 tonnes of marginally economic in-situ resources, 14,000 tonnes of sub-economic in-situ resources and 36,000 tonnes of resources in extensions to the known deposit, hence a total resource of 115,000 tonnes of lithium. Although Anstett et al. (1990) also stated the economic resources are 30,400 tonnes of lithium. Wietelmann and Bauer (2000) stated that Clayton Valley contains 700,000 tonnes of lithium.

Garrett (2004) stated the reserves were originally estimated to be 115,000 tonnes of lithium, however others estimated initially 382,000 tonnes of lithium. Tahil (2008) stated that the reserves estimated in 1992 were 118,000 tonnes of lithium, and estimated that resources were 300,000 tonnes of lithium. Wietelmann and Bauer (2000) stated that Clayton Valley has 40,000 tonnes of recoverable lithium. Tahil (2007) claims that 0.25 million tonnes of lithium carbonate (47,000 tonnes of lithium) is recoverable. Evans (2008b) and Yaksic and Tilton (2009) stated the reserves

TABLE S.2. Reserves and resources for Silver Peak (Mt) (Kesler, 1978)

	Reserves		Resources
	Proved	Probable	Possible
Silver Peak ore	202.25		386.25
Silver Peak grade	0.02		0.02
Silver Peak Li	0.0405		0.0773

are 40,000 tonnes of lithium. Gruber and Medina (2010) assumed the resources were 300,000 tonnes based on the work by Tahil (2008).

S.1.2. Searles Lake.

S.1.2.1. *General.* Searles Lake is a dried up lake in California. Searles lake has an area of 100 km^2 (Garrett, 2004). Production at the lake began in 1916, and in 1936 lithium was extracted and sold to Foote Minerals, until 1951 when a carbonate plant commenced operation, production ceased in 1978 (Garrett, 2004).

Yaksic and Tilton (2009) stated the evaporation rate is 1000 mm/y. The surface area of the lake is 100 km^2 (Garrett, 2004). Tahil (2008) stated the lake is very porous at 35%, and is 8m deep with a brine density of 1.3 g/mL. Yaksic and Tilton (2009) stated the Mg:Li ratio is 125. Harben and Edwards (1997) state the lithium concentration is 70 ppm of lithium. Searles Lake contains 50-80 ppm lithium (Garrett, 2004; Tahil, 2008). Tahil (2008) stated that the concentration left in brine is around 50ppm lithium. Yaksic and Tilton (2009) stated the grade is 0.0065%. The lithium was concentrated to 140 ppm lithium (Garrett, 2004). The brine concentrations are shown in Table S.3.

TABLE S.3. Analysis of the Searles Lake brine in wt.% (Garrett, 2004)

	Na	K	Ca	Li	As	Cl	SO_4	CO_3	B	Br	S	P	F	I	ρ^a
Upper	11.08	2.53	16^b	54^b	144^b	12.30	4.61	2.72	2990^b	846^b	330^b	300^b	54^b	12^b	1.29
Lower	11.84	1.57		60^b		10.81	4.44	3.84	4120^b	537^b	1560^b	190^b	20^b	20^b	1.30
Evap.	8.32	10.62		139^b	3480^b	13.55	1.06	3.56	14810^b	7390^b	2840^b	2400^b		360^b	1.34

[a]density
[b]ppm

S.1.2.2. *Reserves/Resources.* Kesler (1978) estimated probable lithium reserves of 23,700 tonnes of lithium at a grade of 0.005 wt.%. Garrett (2004) stated that Searles lake has 31,600 tonnes of lithium reserves, although Yaksic and Tilton (2009) stated Searles lake has 31,600 tonnes of lithium resources. Tahil (2008) states the total lithium in the lake is 18,200 tonnes. Evans (2008a) stated that Searles Lake has an improbable future production and Tahil (2008) stated that the remaining resources are too small to be exploited.

S.1.3. Great Salt Lake.

S.1.3.1. *General.* The Great Salt Lake currently extracts NaCl, magnesium chloride and potassium sulfate (Tahil, 2008). The evaporation rate is 1800 mm/y (Harben and Edwards, 1997; Garrett, 2004; Tahil, 2008; Yaksic and Tilton, 2009) and the Mg:Li ratio is 250 (Tahil, 2007, 2008; Yaksic and Tilton, 2009). Harben and Edwards (1997) stated the Great Salt Lake has a concentration of 28-60 ppm lithium. Garrett (2004) stated the southern end of the lake has a lithium concentration of 18-43 ppm and the northern end 40-64 ppm. The lithium concentration is 0.004% lithium (Tahil, 2007; Yaksic and Tilton, 2009). The density of the lake is 1.218 g/mL (Pavlovic and Fowler, 2004).

Garrett (2004) stated that after magnesium is removed the end liquor contains 600 ppm lithium and after potassium sulfate has been removed the brine has 700-1600 ppm lithium. The lake could have 41 tonnes per year of lithium production from the 700-1600 ppm concentrated brine (Garrett, 2004). The analysis of the Great Salt lake brine is shown in Table S.4.

TABLE S.4. Analysis of the Great Salt Lake brine in wt.% (Garrett, 2004; Pavlovic and Fowler, 2004; Wietelmann and Bauer, 2000)

	Na	K	Mg	Ca	Li	As	Cl	SO_4	CO_3	HCO_3	B	Br	ρ^a
South	3.7-8.7	0.26-0.72	0.5-0.97	0.026-0.036	18^b	138^b	7-15.6	0.94-2	5^b	600^b	18^b	55^b	∼1.1
Mg Plant	0.5	0.8	7.5		600^b		20.3	4.4			540^b		
GSL[c]	0.118	0.058	8.55	50^b	1160^b			2.46			700^b	2120^b	1.344
Pavlovic[d]	8.0	0.65	1.0	0.016	0.004		14.0	2.0			0.006		1.218
Ullmanns[e]	7.0	0.4	0.8	0.03	0.004		14.0	1.5					

[a]density
[b]ppm
[c]Maximum evaporated brine from the GSL solar ponds
[d]Pavlovic and Fowler (2004)
[e]Wietelmann and Bauer (2000)

S.1.3.2. *Reserves/Resources.* Tahil (2008) stated that circa 1978, the recoverable component of resources was 286,000 tonnes of lithium. Harben and Edwards (1997) stated that the recoverable resources are 286,000 tonnes of lithium. Wietelmann and Bauer (2000) stated the lake contains 450,000 tonnes of lithium, and that 260,000 tonnes of lithium is recoverable. Garrett (2004) claims Great Salt lake has 526,000 tonnes of lithium reserves, although later states the value is the total lithium in the lake. Evans (2008a) stated the lake contains 520,000 tonnes of lithium. Tahil (2008) and Yaksic and Tilton (2009) state the 526,000 value from Garrett (2004) is a resource. Evans (2008b) states that there is potential for 260,000 tonnes of lithium to be extracted from the Great Salt lake. Evans (2008a) stated that because of the low grade the resource should be considered a potential reserve, and Gruber and Medina (2010) argued that the low quality of lithium means it should be excluded as a resource.

S.2. Geothermal Brine

S.2.1. Salton Sea.

S.2.1.1. *General.* Salton Sea is a geothermal brine in southern California, which is currently used for geothermal power (Garrett, 2004). Calenergy current operates a geothermal power station there and between December 2002 and September 2004 operated a zinc recovery plant, however zinc recovery was limited and hence shut (Tahil, 2008). The depth of the geothermal brine ranges from 500 - 3000 m (Garrett, 2004). Tahil (2008) stated the underground, superheated, pressurized brine is approximately 4km^3 in volume.

Harben and Edwards (1997) state that the Salton sea, contains 0.02% lithium, whilst Yaksic and Tilton (2009) state it is 0.022%. The lithium concentration ranges from 100-400 ppm of lithium (average 200ppm) (Garrett, 2004). The sea extends into Mexico, however there the concentration is only 5 - 100 ppm of lithium (Garrett, 2004). Tahil (2008) stated that the lithium content is 100 - 250 ppm (average 200ppm). Tahil (2008) stated that lithium concentrations at wells are 117-245 ppm and states that Obsidian Energy estimates it to be 187 ppm.

The evaporation rate is estimated to be 1800 mm/y (Yaksic and Tilton, 2009). The Mg:Li ratio is 1.3 (Yaksic and Tilton, 2009). The brine has a density of 1.2g/mL (Tahil, 2008). Pilot plants concentrated the brine to 400 ppm of lithium after potash extraction, but lithium was not produced (Garrett, 2004).

Simbol mining plan to develop spent brine for lithium extraction and hopes to produce 100,000 tpy of lithium carbonate (19,000 tonnes/y lithium) (Tahil, 2008). If correct, this project by itself would almost double the current lithium production, however Tahil (2008) considers the 19,000 T/y of lithium to be maximum production at an unknown point in the future. The analysis of the brine is shown in Table S.5.

TABLE S.5. Analysis of the Salton sea brine in ppm (Garrett, 2004)

	Na	K	Mg	Ca	Li	Cl	SO_4	B	Br	ρ^a	pH
Salton Sea	50,000-70,000	13,000-34,200	700-5,700	22,600-39,000	100-400	142,000-209,000	42-50	400-500	109-200	1.18-1.26	4.6-5.5

[a]density

S.2.1.2. *Reserves/Resources.* Harben and Edwards (1997) stated that the potential reserves are more than 840,000 tonnes of lithium. Garrett (2004) stated that Salton sea has 1 million tonnes of lithium reserves. Evans (2008a) stated that Salton sea has reserves of ∼316,000 tonnes of lithium. Tahil (2008) and Yaksic and Tilton (2009) stated that Salton sea has 1 million tonnes of resources. Gruber and Medina (2010) quoted the full report from Clarke and Harben (2009) that indicated that Brawley has 1 Mt of lithium resources, Brawley is a town located directly South of the Salton Sea and above the Mexico border, as the Salton Sea is believed to extend into Mexico, it is assumed that this resource is referring to Salton Sea. Gruber and Medina (2010) stated the resources from the Salton Sea were 316,000 tonnes but that it could be as high as 960,000 tonnes of lithium.

S.3. Oil brine

S.3.1. Smackover.

S.3.1.1. *General.* In Arkansas the brines are used to recover bromine and the brines are located at a depth of 1800 - 4800 m (Garrett, 2004). Harben and Edwards (1997) stated that oil field brines have recorded concentrations as high as 280 ppm lithium. Wietelmann and Bauer (2000) stated the Texas oil brines contain up to 692 mg/L of Lithium, but rarely exceeds 100 mg/L. The Smackover brines have a concentration of 50-572 ppm of lithium, the Texas brine average 386 ppm and Arkansas brine averages 365 ppm (Garrett, 2004). Tahil (2008) estimates the brine has a density of 1.2 g/mL.

The Smackover brines in Arkansas have a Mg:Li ratio of ∼20 (Wietelmann and Bauer, 2000). Tahil (2008) however claims the Mg:Li is 4-5 for Arkansas. The Mg:Li ratio for the Smackover oil field brines is 20 (Yaksic and Tilton, 2009).

Tahil (2008) claims that evaporation ponds are not viable due to the need to reinject the brine to maintain oil production. Tahil (2008) estimates that 11,000 tonnes/y of lithium could potentially be produced. An analysis of the brines is shown in Table S.6.

TABLE S.6. Analysis of the Smackover oilfield brine in wt.% (Garrett, 2004)

	Na	K	Mg	Ca	Li	Cl	SO_4	B	Br	ρ^a
Collins (1976)	5.69	0.24	0.29	2.91	146^b	14.45	375^b	123^b	0.263	1.180
Dow (1984)	6.70	0.28	0.35	3.45	170^b	17.17	450^b		0.313	
Texas[c]	5.49	0.59			386^b					1.171
Arkansas[c]	5.98	0.51			365^b			366^b		1.229

[a]density
[b]ppm
[c]High lithium

S.3.1.2. *Reserves/Resources.* Garrett (2004) stated that the lithium reserves are 1 million tonnes of lithium, however Yaksic and Tilton (2009) stated this is resources. Evans (2008a) stated the Smackover formation oil brines have a possible reserve of 750,000 tonnes of lithium, which Gruber and Medina (2010) stated is a resource estimate and is the resource value Gruber and Medina (2010) selected.

S.4. Ore

S.4.1. Pala/Stewart. The mainly lepidolite with small amounts of amblygonite and spodumene at Pala district, California was mined during 1900 - 1927 (Garrett, 2004). The deposit contained 0.1% FeO and 0.02% Fe_2O_3 (Garrett, 2004).

S.4.2. Blackhills. The Black hills deposit was located in South Dakota and production began in the region in 1898 (Garrett, 2004). The largest mine there was the Etta mine which started in 1908 and ran for nearly 50 years (Garrett, 2004). By 1944, the cumulative lithium ore production from the Black hills was 7,127 tonnes of lepidolite, 7,678 tonnes of amblygonite, 22,619 tonnes of spodumene, with a small amount (100 tonnes) of triphylite (Garrett, 2004). The lithium grade ranged from 0.5 – 3 % of spodumene ore, and 1.18 – 2.15 % lithium for amblygonite. The FeO content was 0.02 % and the Fe_2O_3 content was 0.03% (Garrett, 2004). Production in South Dakota stopped in 1969 (Garrett, 2004).

S.4.3. North Carolina.

S.4.3.1. *General.* North Carolina has a large lithium deposit, and is a 48 km long belt (Garrett, 2004). The average grade of lithium is 0.7% (Garrett, 2004) although Evans (2008b) stated the grade is 0.6% lithium. Typically the ore has 15-20% spodumene (Garrett, 2004). There were two mines on this belt, Foote (Chemetall) which mined near Kings Mountain, and FMC (LCA) which mined near Cherryville. Kesler (1961) stated the spodumene concentration at the Foote mountain was 20% spodumene. Refining of the lithium ores was done in Bessemer. The region had been mined since the early 1900's however significant production began when Foote (Chemetall) started the Kings Mountain mine in 1953, and FMC (LCA) started the Cherryville mine in 1969 (also claimed 1968 and mid 1960's) (Garrett, 2004). The deposit is shown in Figure S.2.

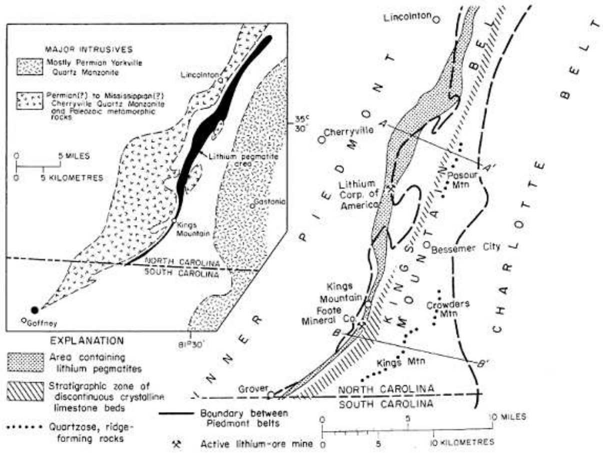


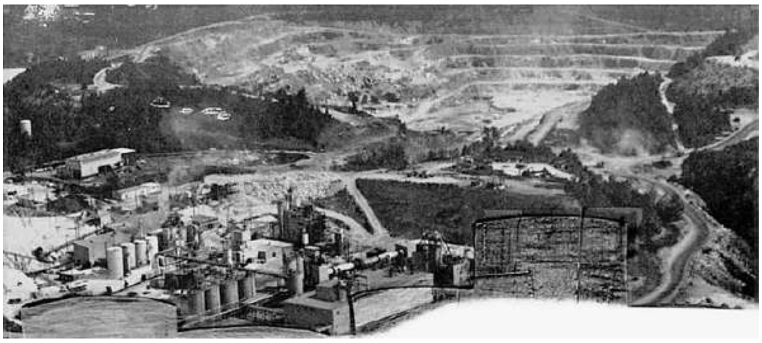
FIGURE S.2. The North Carolina lithium belt (Garrett, 2004)

The Kings Mountain mine is shown in Figure S.3. The Kings Mountain mine had been operated by Solvey Process Co during 1943 - 1946 using strip mining (Garrett, 2004). Foote bought the deposit in 1951, and it had a 327 tonnes per day capacity (Garrett, 2004). Kings Mountain spodumene deposit, has 0.08-0.1% FeO and 0.7-0.8% Fe_2O_3 (Garrett, 2004). Yaksic and Tilton (2009) stated that Kings Mountain has a grade of 0.69% lithium. The ore averaged 15-20% spodumene (Garrett, 2004). The top 1.8 - 2.4 m of top rock was considered overburden (Garrett, 2004). During 1954 -1956 Foote did extensive drilling and established a new open pit mine (Garrett, 2004). Anstett et al. (1990) stated and Tahil (2008) reiterated that the production capacity was 1,540 tonnes of lithium. The mine was placed on standby in 1984, before being closed in 1991 (Garrett, 2004), although Tahil (2008) stated it was shut in 1986. The analysis of the Kings Mountain ore is shown in Table S.7.

TABLE S.7. The analysis of the Kings Mountain ore in wt.% (Göd, 1989)

Component	Ore
SiO_2	74.6
Al_2O_3	16.4
Na_2O	3.3
K_2O	2.4
Li_2O	1.5
Total	98.2

Figure S.4 shows the Cherryville mine. The Cherryville open pit spodumene mine had a grade of 0.7% lithium and was concentrated to 3% lithium (initially 3.73%) (Garrett, 2004). Although Yaksic and Tilton (2009) stated that the grade is 0.68% lithium. Harben and Edwards (1997)



A Garrett (2004)

B Horton (2008)

FIGURE S.3. Kings Mountain mine

stated that the mine ore was 20% spodumene. Anstett et al. (1990) stated that Bessemer City had a capacity of 3070 tonnes of lithium. Tahil (2008) stated that Bessemer production plant had a capacity of 15,000 tonnes per year of lithium carbonate (2,800 tonnes per year of lithium). Harben and Edwards (1997) stated that the mine was phasing out production in 1997. The mine appears to have shut down in 1998 (Garrett, 2004).

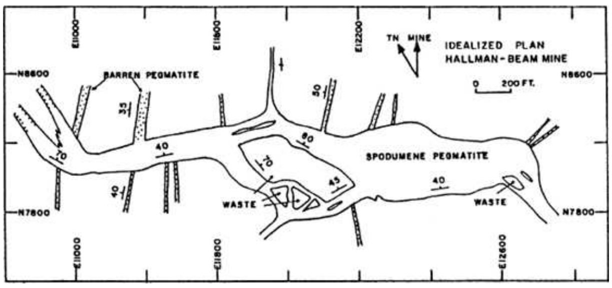


FIGURE S.4. Cherryville mine (Garrett, 2004)

S.4.3.2. *Reserves/Resources.* Kesler (1961) stated that the reserves of ore in the Kings Mountain mine (Foote) were 18.8 million tonnes of ore at 1.53% lithia (0.71% lithium, 133,500 tonnes of lithium). Kesler (1978) has reserve and resource estimates for North Carolina as shown in Table S.8

TABLE S.8. Lithium reserves and resources in North Carolina in Mt (Kesler, 1978)

	Reserves		Resources
	Proved	Probable	Possible
FMC Ore	33.75	5.95	22.6
FMC grade	0.68	0.69	0.65
FMC Li	0.2295	0.0411	0.1469
Foote ore	22.3	3.4	18.9
Foote grade	0.7	0.7	0.7
Foote Li	0.1561	0.0238	0.1323
Unexplored Ore			750
Unexplored grade			0.69
Unexplored Li			5.175
N. Carolina Ore	56.05	9.35	793.1
N. Carolina Li	0.3856	0.0649	5.4614

Kunasz (1983) total potential resource in the region is estimated at 754 million tons. Wietelmann and Bauer (2000) stated that the region may contain 2.8 million tonnes of lithium.

Garrett (2004) is a little confusing in the reserves and resources of North Carolina. Garrett (2004) stated that North Carolina has 71,000 tonnes of lithium reserves. Garrett (2004) further stated that more extensive drilling by Foote determined ore reserves of 29 million tonnes of ore at 0.7% lithium (203,000 tonnes of lithium) and inferred reserves of 14 million tonnes of ore (98,000 tonnes of lithium at 0.7% lithium) and that the FMC mine had proven and probable reserve of 27.5 million metric tonnes of ore at 0.7% lithium (192,500 tonnes of lithum), hence a total of 493,500 tonnes of lithium reserves. Finally Garrett (2004) stated that the North Carolina belt contains 185,000 tonnes of proven lithium (resources? Reserves?) and "perhaps twice that in total ore".

Evans (2008a) estimates that Foote had reserves of 150,000 tonnes of lithium before closing, FMC had 80,000 tonnes of lithium reserves, and that undeveloped recoverable resources along the 48 km long belt are around 2.6 million tonnes of lithium (375 tonnes of ore) at a depth of up to 1500 m. Yaksic and Tilton (2009) state that Kings Mountain has 200,000 tonnes of resources, Cherryville has 335,000 tonnes of resources and that undeveloped resources are 2.6 million tonnes of lithium. Gruber and Medina (2010) assumed that North Carolina has 5.454 million tonnes of lithium resources.

S.5. Hectorite

S.5.1. McDermitt.

S.5.1.1. *General.* The deposit is a hectorite clay deposit. Western lithium intend to mine the deposit and produce lithium carbonate (Ajie et al., 2009). The McDermitt Caldera deposit is located (Nevada/Oregon) and is also referred to as Kings Valley Nevada. The deposit has 0.65% lithium and the cut off grade is 0.2% lithium and is anticipated to have a 60% recovery (Ajie et al., 2009). Although Yaksic and Tilton (2009) stated that the grade is 0.24 - 0.53% lithium. Western Lithium aim to operate a mine starting in 2014, the mine life is estimated at 18 years (15 years minimum) and hopes to produce 25,000 tonnes per year of lithium carbonate (4,700 tonnes/y of lithium) (Ajie et al., 2009). Although Western Lithium (2010) stated the production will be 27,700 tonnes per year of lithium carbonate (5,200 tonnes/y of lithium). A summary of the planned mine is shown in Table S.9. The depth of the deposit is shown in Figure S.5, the mine design is shown in Figure S.6 and the process flowsheet is shown in Figure S.7. The production by year for the mine is shown in Table S.10 and the project costs are shown in Table S.11.

TABLE S.9. The McDermitt pit mine parameters (Ajie et al., 2009)

Item	Total/Average
Mineral processing cost	\$50/tonne
Mining cost	\$2/tonnes
Pit-wall angle	45^{o}
Selling price for lithium carbonate	\$3.00/lb
Mining recovery factor	100%
Overall plant recovery	65%
Lithium cutoff grade	0.27%
Minimum mine life required	15 years
Target output lithium carbonate	25,000 tonnes/year

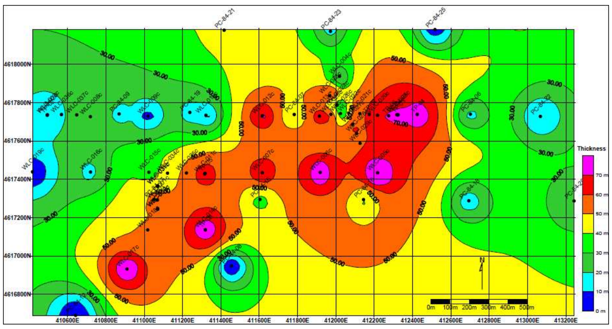


FIGURE S.5. Thickness of the PCD lenses of the McDermitt Caldera deposit (Ajie et al., 2009)

S.5.1.2. *Reserves/Resources.* Chevron in 1985 estimated that resources were 694 million tons of ore (630 million tonnes) and 2.276 million tons of lithium (∼2 million tonnes) as shown in Table S.12 (Ajie et al., 2009). Based on the Chevron estimate, Evans (2008a) and Gruber and Medina (2010) stated that McDermitt Caldera has 2 million tonnes of hectorite resources. Western Lithium (2010) shows the lithium indicated and inferred resources for various cut of grades for: the PCD deposit in Table S.13 and the South deposit in Table S.14, Ajie et al. (2009) indicated that the cut of grade is 0.2% lithium.

S.5.2. Elsewhere.

S.5.2.1. *General.* Hectorite clays are lithium bearing clays, first discovered in Hector California (Kunasz, 2006). Hectorite concentrations range from 0.24 to 0.53% lithium (Garrett, 2004). Kunasz (2006) indicated the following lithium concentrations for various US deposits: Hector

TABLE S.10. The McDermitt mine planned production profile (Ajie et al., 2009)

Year	Lithium Carbonate kt	Potassium Sulfate kt
1	28	125
2	27	138
3	27	126
4	27	111
5	27	91
6	27	97
7	27	121
8	27	95
9	27	102
10	27	115
11-15	137	548
16-18	88	405
Total	496	2074

TABLE S.11. The McDermitt mine project and operating costs (Ajie et al., 2009)

Description	Life of Mine Total US$000's	Unit cost US$/total tonnes	Unit cost US$/Li tonnes
Mining-Open pit	282,538	2.57	566.57
Processing	1,878,627	17.07	3,767.17
Others:			
Owner's Costs	64.416	0.59	129.17
Royalties	184,842	1.68	370.66
Capital Depreciation	421,976	3.83	846.18
Total	2832,399	25.73	5679.75

TABLE S.12. The Chevron resource estimate for the McDermitt Caldera deposit (Ajie et al., 2009)

Lens	No. of holes	Area (ha)	Deposit thickness (m)	Waste Thickness (m)	Average Grade (% Li)	deposit Mt	Lithium Mt
North	21	552	18.0	19.5	0.31	178	0.546
North Central	10	151	20.1	12.5	0.34	54	0.188
South Central	7	93	16.2	7.0	0.37	34	0.122
South	52	985	18.0	13.1	0.33	320	1.062
PCD	6	134	18.0	17.1	0.34	44	0.147
Total	96	1,916	-	-	0.33	529	2.064

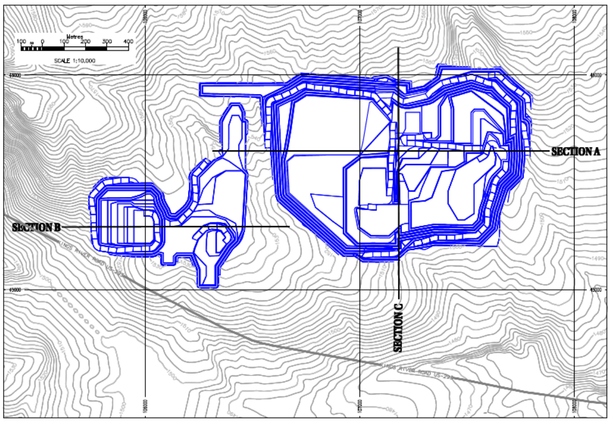


FIGURE S.6. Proposed open pit mine at the McDermitt Caldera deposit (Ajie et al., 2009)

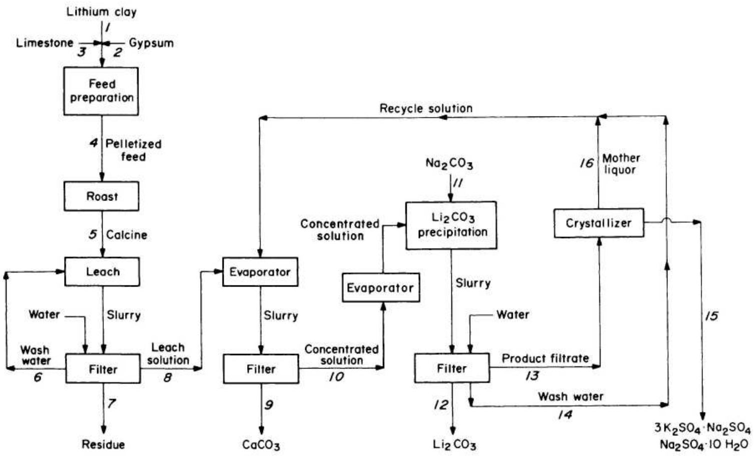


FIGURE S.7. Proposed lithium carbonate plant at the McDermitt Caldera deposit (Ajie et al., 2009)

TABLE S.13. The indicated and inferred resources for the PCD deposit in McDermitt Caldera (Western Lithium, 2010)

	Indicated Resources			Inferred Resources		
Cut off Li%	Mt clay	Li%	kt lithium	Mt clay	Li%	kt lithium
0.175	60	0.253	152	54	0.252	136
0.200	48	0.269	129	42	0.269	113
0.225	36	0.288	104	30	0.291	87
0.250	26	0.308	65	21	0.317	67
0.275	18	0.327	59	16	0.334	53
0.300	12	0.346	42	10	0.358	36

California, 0.53%; Clayton valley hectorite, 0.24 - 0.35%; Spor Mountain Utah, 0.11%; Yavapai Arizona 0.1%; Tertiary clays Kramer California - 0.19%.

S.5.2.2. *Reserves/Resources.* Garrett (2004) stated that the total USA hectorite reserves is 15.1 million tons of lithium (13.7 million tonnes of lithium).

TABLE S.14. The indicated and inferred resources for the South deposit in McDermitt Caldera (Western Lithium, 2010)

	Indicated Resources			Inferred Resources		
Cut off Li%	Mt clay	Li%	kt lithium	Mt clay	Li%	kt lithium
0.15	127	0.25	318	74	0.23	170
0.20	95	0.27	257	47	0.26	122
0.25	50	0.31	155	20	0.30	60
0.300	27	0.34	92	9	0.34	31

APPENDIX T

Zaire

T.1. Ore

T.1.1. Manono/Kitotolo.

T.1.1.1. *General.* The deposit is a spodumene deposit (Wietelmann and Bauer, 2000). Anstett et al. (1990) stated the grade is 0.98% lithium, although Yaksic and Tilton (2009) stated the grade is 0.58% and Evans (2008b) stated the grade is 0.6% lithium. The deposit is 2200 km away from a port (Tahil, 2008). Kunasz (2006), stated that the Manono deposit is not economic due to a lack of transportation facilities. Garrett (2004) stated that the deposit has 10-25% spodumene, but that from 1929 - 1991 only columbite and cassiterite have been mined.

T.1.1.2. *Reserves/Resources.* Kesler (1978) has the reserve and resources for Manono shown in Table T.1.

Anstett et al. (1990) stated the uneconomic and extensions of known deposit resources is 50 million tonnes of ore, with the marginal and sub-economic resources at 305,640 tonnes of lithium, and 184,360 tonnes of lithium in extensions to known deposit. Wietelmann and Bauer (2000) stated that Manono reserves are estimated at 2 million tonnes of lithium. Garrett (2004) stated that Manono has reserves of 309,000 tonnes of lithium.

Evans (2008a) claimed Manono could contain 2.3 million tonnes of lithium, and this is the value that Yaksic and Tilton (2009) quoted are resources. Tahil (2008) claimed the deposit has 309,000 tonnes of lithium. Evans (2008b) claimed a value of 2.34 million tonnes of lithium is recoverable (resources were reduced by 75% to account for mining). Clarke and Harben (2009) estimated 1.145 Mt of lithium reserves for Zaire.

TABLE T.1. Reserves and resources for Manono (Mt) (Kesler, 1978)

	Reserves		Resources
	Proved	Probable	Possible
Manono ore	35	85	400
Manono grade	0.6	0.6	0.6
Manono Li	0.21	0.51	2.4

APPENDIX U

Zimbabwe

U.1. Ore

U.1.1. Bikita.

U.1.1.1. *General.* The mine was first opened in 1911 to recover tin (Garrett, 2004). Kunasz (2006) stated that Bikita produces petalite and spodumene concentrate, however Wietelmann and Bauer (2000) claimed Bikita has mostly petalite and lepidolite. Garrett (2004) stated the petalite was mined in an open pit, but that amblygonite was selectively hand mined from outcrops, and that lepidolite was first mined from 1954 (however production statistics from the USGS and minerals UK go back to 1950).

Bikita has an average grade of 1.4% lithium (Kunasz, 1983; Yaksic and Tilton, 2009). Although Ebensperger et al. (2005) and Tahil (2008) stated the grade is 1.4% lithia (0.65% lithium), and Anstett et al. (1990) stated the average grade is 1.25% of lithium. The overburden of weathered country rock, and a low grade lithium ore (which was stockpiled for future use) had a ratio was 1:1 (Garrett, 2004). A graph of the mine is shown in Figure U.1.

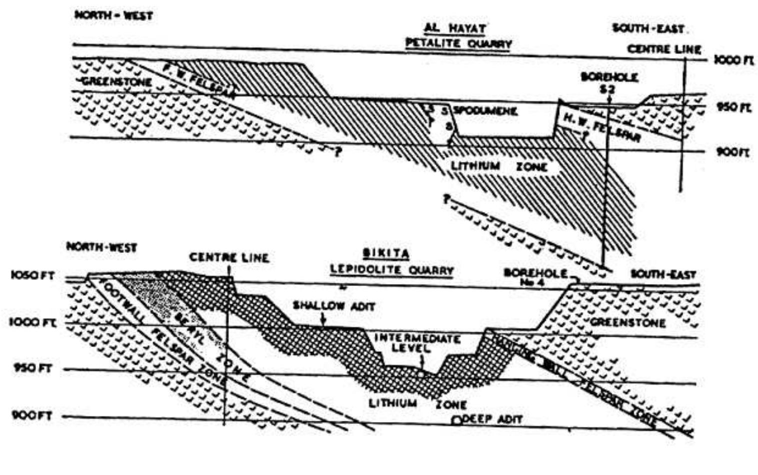


FIGURE U.1. Side view of the Bikita mine (Garrett, 2004)

Anstett et al. (1990) indicated that Bikita has a production capacity of 530 tonnes of lithium. Ebensperger et al. (2005) stated that in 2001 the production capacity was 55,000 tonnes of ore and sales were 41,000 tonnes of ore.

Garrett (2004) stated that the production was hand sorted between 1952 and 1960, and a 10,000 tonnes/y media separator was installed in the mid 1980's. Harben and Edwards (1997) stated that petalite reserves are in decline, but that the separating plant built in the 1980's allowed petalite in waste stockpiles to be recovered (4.4% lithia - 2% lithium) adding 30 years to the mine life. Bakita increased spodumene production to 10,000 tonnes per year in 1994 (Harben and Edwards, 1997). Analysis of the minerals is shown in Table U.1.

TABLE U.1. Analysis of the Bikita minerals wt.% (Garrett, 2004)

	Petalite	Eucryptite	Spod/Quartz[a]	Lepidolite	Amblygonite	pollucite
SiO_2	76.79	73.98	76.50	56.24	1.62	47.09
Al_2O_3	16.85	18.15	17.09	24.65	33.36	17.41
Li_2O	4.36	4.98	4.12	3.64	8.60	0.41
Rb_2O	0.00	0.00	0.00	2.71		0.91
Cs_2O	0.00	0.00	Trace	0.31	0.00	26.60
K_2O	0.00	0.23	0.71	7.20	0.20	2.00
Na_2O	0.46	0.51	0.94	0.26	1.00	3.02
CaO	0.31	0.23	0.36		0.00	0.00
MgO	0.21	0.07	Trace		0.72	0.00
P_2O_5	0.00	0.00	0.08		43.97	0.30
F	0.02	0.02		5.10	3.48	
Fe_2O_3	0.05	0.06	0.017			
TiO_2	0.00	0.00	0.00			0.00
MnO	0.04	0.12			0.03	
BeO	0.006	0.01				
Total	99.75	99.92	100.46	101.23	99.22	99.94

[a]Spodumene-Quartz intergrowth

U.1.1.2. *Resources/Reserves.* Kesler (1978) has the reserves and resources for Bikita shown in Table U.2.

TABLE U.2. Reserves and resources for Bikita (Mt) (Kesler, 1978)

	Reserves		Resources
	Proved	Probable	Possible
Bikita ore	4.5	0.9	5.4
Bikita grade	1.4	1.4	1.4
Bikita Li	0.063	0.0125	0.0756

Garrett (2004) stated that in 1961 Bikita had 6 million tons (5.4 million metric tonnes) of proven reserves of ore at 1.35% lithium (72,900 tonnes of lithium), in 1979 it was 12 million tons of proven ore (10.9 million metric tonnes) and 1.4% lithium (152,000 tonnes of lithium). Kunasz (1983) estimated that Bikita has proved reserves of 12 million tons of ore, at 1.4% lithium. Anstett et al. (1990), stated the identified economic resources are 4.1 million tonnes of ore (55,400 tonnes of lithium). Anstett et al. (1990) places the recoverable portion of the resources at 44,300 tonnes of lithium.

Wietelmann and Bauer (2000) stated that Bikita contains 75,000 - 100,000 tonnes of lithium. Garrett (2004) stated that Bikita has 23,000 tonnes of lithium reserves. Evans (2008a) stated the proved, probable and possible resources are 56,700 tonnes of lithium. Tahil (2008) stated that the proven reserves are 23 Mt of ore, and hence 150,000 tonnes of lithium in place (using 1.4% lithia grade). Tahil (2008) further stated that the USGS reserve value of 23,000 tonnes of lithium is realistic. Yaksic and Tilton (2009), stated that Bikita has resources of 56,700 tonnes of lithium. Gruber and Medina (2010) assumed the Yaksic and Tilton (2009) value of 56,700 tonnes of lithium is correct.