American Pacific Borate and Lithium, ABR.AX

Supplying the critical element

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Executive summary

American Pacific Borate and Lithium (ABR.AX) is developing the Fort Cady borate and lithium project in California, USA. ABR acquired the project in May 2017. A Scoping Study was completed in December 2017, and a Definitive Feasibility Study (DFS) in December 2018, just 19 months after the acquisition. In January 2019, ABR released a low-capex ‘enhanced’ version of the DFS, that split Phase 1 into two parts, and is now considered ‘base case’. Phase 1A comprises the Phase 1 sulphate of potassium (SOP) line plus a commercial scale boric acid plant. Phase 1B is the full 82,000 tpa Phase 1 boric acid plant.

Looks like a 10-bagger: Based on the January 2019 DFS, the project has a post-tax, unlevered NPV$_{10}$ of US$1,083m, with an IRR of 41% and an initial capex requirement for Phase 1A of just US$37m. This is an incredibly low capex figure to get a project of this scale up and running. Despite these strong metrics, ABR’s current market capitalisation is about 2% of NPV. Assuming total initial capital (including working capital) for Phase 1A of US$50m, debt financing, 50m warrants at A$0.50 per share offered as an incentive to debt providers, a further US$80m in debt to fund Phase 1B, and a fair EV valuation 12 months from now of 30-50% of NPV, ABR could attract an EV valuation of US$325m to US$542m. This equates to a valuation of A$1.10-A$2.21 per share, 7-14x the current share price.

Lower capex, much lower dilution: Junior companies with big projects often end up heavily diluting shareholders when the real money needs to be spent. The brilliance of splitting Phase 1 into two parts is that this should now be avoided. At US$50m all in, Phase 1A is financeable with debt plus warrants. With 1A in production, financing Phase 1B will be easier and cheaper. By splitting Phase 1 into two, management have been greedy on behalf of shareholders. That’s a good thing.

Opportunity knocks: ABR shares are still trading at levels seen in 4Q18, the tail end of a horrible year in junior mining. So far, the market has failed to recognise the opportunity in ABR that this presents.

Compelling project with substantial cash flows: Based on the DFS, Fort Cady will ultimately produce ~408,000 tpa of boric acid and ~109,000 tpa of SOP. ABR will become only the second major producer of calcium-based borates globally, and only the second producer of SOP in the US. The project is expected to generate EBITDA of US$345m in the first full year of production.

Splitting Phase 1 is valuable risk mitigation: ABR will run a five-well commercial scale boric acid operation in Phase 1A to assess various wellfield injection and brine recovery options. This will reduce technical and engineering risks in the larger scale Phase 1B. There is scope to reduce the total number of wells meaning potential savings in both capital costs from fewer wells and operating costs from more efficient brine recovery.

Fort Cady is a past producing asset: Project risks are also mitigated by the fact there has been extensive historical development. There was limited-scale solution mining in 1981, and pilot scale operations in 1987-1988. The project was fully approved for commercial scale operations in 1994. Feasibility studies, detailed engineering and test works occurred in the late-1990s and early-2000s. This included a second pilot plant from 1996 to 2001. More than US$60m (about 3x ABR’s market cap.) has been spent on project development to date.
Fort Cady hosts a strategically important asset: Colemanite is a calcium-based borate that does not contain sodium. This is important because in applications such as E-glass, the most common form of glass fibre, and some types of borosilicate glass, such as those used in TFT-LCDs, low- or no-sodium borates are used. Colemanite resources are rare and vital. At present, Turkish state-owned entity Eti Maden has a virtual monopoly in mining colemanite on a commercial scale. Fort Cady hosts the only other major, commercially viable colemanite deposit in the West, and thus offers a vital alternative source of supply.

Cooperation agreements with the Chinese majors: In May 2018, ABR secured cooperation agreements with Sinochem Hebei Corp, a subsidiary of China’s state-owned Sinochem Group, and with China National Fiber Corp, a subsidiary of China National Machinery Industry Corp (usually known as ‘Sinomach’). These are substantial groups; in 2018, Sinochem Group was ranked 98th in Fortune Global 500. Sinomach was ranked 334th. (For comparison, Rio Tinto was ranked 278th). It is no surprise the Chinese were quick off the mark; China is the largest market for borates and a significant net importer. That two of China’s largest and most established state-owned enterprises have entered into these agreements is a testament to the strategic value of the Fort Cady project.

Strategic possibilities abound: Hosting the only meaningful colemanite resource in the West, and as only the second producer of SOP in the US, ABR is strategically significant. Borates are so pervasive in modern society – they are used in many industries and applications – that ABR could effectively partner with a number of major US and European based groups highlighted in this report. One example might be for ABR to partner with a group involved in glass or glass fibre. Another possibility would be to secure some type of offtake financing with one of the existing Chinese partners. Another might be to finance the SOP project separately, with ABR benefiting from US distribution. Strong interest in the project is expected from both industrial minerals, and speciality fertilisers groups.

Fort Cady could be worth US$3.3bn to a strategic: A range of major industrial minerals and fertiliser companies are trading at an average of ~9.5x 2018 EV/EBITDA. Applying this average multiple to ABR’s expected EBITDA in the first full year of production suggests a longer-term valuation to a US or European group of as much as US$3.3 bn. That is, more than 150x ABR’s current market cap.

Robust outlook for boron demand: Boron and borates are used in a multitude of modern applications from abrasives to water treatment, and from soap to nuclear power plants, and in lithium ion batteries and hydrogen fuel cells. The global market for boric acid (H₃BO₃) reached 3.9m tonnes in 2017, with the market expected to continue growing at ~4% pa. Borates demand is being driven by the ‘big picture’ trends of urbanisation, energy efficiency, and food security. It may come as a surprise to learn that in US dollar terms, the global borates market is about the same size as the lithium market, at ~US$3.0bn.

Few new projects expected to come on stream: The borates market is essentially a duopoly with Eti Maden and Rio Tinto (RIO.L) together controlling ~80% of the world demand. Globally, there are few occurrences of commercially viable borate deposits; visibility on new projects other than Fort Cady is poor. Some projects plan to mine borates as a by-product to lithium, but these are earlier stage, and rely on processing new minerals, something that will take time to learn. The Fort Cady processing route is based on prior feasibility study level work, well-established chemistry and standard processing equipment. ABR offers the purest exposure to the boron market, the most advanced project, and the lowest capex.
**Strong US demand for SOP:** US SOP demand is expected to grow at ~4.8% pa over the next few years, having grown at almost 5% pa since 2009. A number of factors are driving this growth including the use of newer, higher-yielding crops that extract more sulphur from the ground, the recent popularity of planting in cold soils, and global emission controls which have meant less sulphur deposition from precipitation. SOP is primarily consumed in states that grow high-value or chlorine sensitive crops. California, which has significant areas of chloride sensitive crops such as citrus fruits, avocado, and berries, accounts for more than 35% of US consumption.

In summary, Fort Cady is a hugely valuable project. It hosts a strategically important mineral, is in an excellent jurisdiction, and boasts very low capex costs. It is the most advanced borates project in the market. This, combined with the fact that ABR will be only the second producer of SOP in the US, means the company has a multitude of strategic options. The current share price, being ~2% of NPV, offers investors a great opportunity.

Simon Francis
March 2019
Key financial data

Figure 1: Shareholding structure

<table>
<thead>
<tr>
<th></th>
<th>ABR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share price, 7 March, 2019</td>
<td>A$/share</td>
</tr>
<tr>
<td>Shares on issue</td>
<td>Millions</td>
</tr>
<tr>
<td>Options</td>
<td>Millions</td>
</tr>
<tr>
<td>Fully diluted shares</td>
<td>Millions</td>
</tr>
<tr>
<td>Fully diluted market capitalisation</td>
<td>A$ millions</td>
</tr>
<tr>
<td>Fully diluted market capitalisation</td>
<td>US$ millions</td>
</tr>
<tr>
<td>Cash on hand, 31 December, 2018</td>
<td>A$ millions</td>
</tr>
<tr>
<td>Top 20 shareholders:</td>
<td></td>
</tr>
<tr>
<td>Atlas Precious Metals</td>
<td>~26%</td>
</tr>
</tbody>
</table>

Source: ABR

Key Management:

**Michael X. Schlumpberger**, Managing Director and CEO: Mr Schlumpberger is a qualified mining engineer with over 30 years’ experience in industrial minerals. His background includes management, operations, and maintenance in all aspects of mining, processing, reclamation, and permitting. He has held senior roles with Potash Corporation of Saskatchewan, Passport Potash, and Highfield Resources, and has worked in the United States, Canada, and Europe. Mr Schlumpberger holds an MBA from East Carolina University.

**Anthony Hall**, Executive Director: Mr Hall is a qualified lawyer with 20 years’ commercial experience in venture capital, risk management, strategy and business development. He was Managing Director of ASX listed Highfield Resources Limited from 2011 to 2016. During his tenure, the company’s market cap. grew from A$10m to a fully diluted value of over A$800m, and over A$140m was raised to progress potash projects in Spain. Mr Hall holds a Bachelor of Laws (Hons), Bachelor of Business and a Graduate Diploma of Applied Finance and Investment.

Figure 2: ABR share price chart

Source: ASX
Snapshot of the DFS

- The DFS (January 2019) boasts a post-tax NPV10 of US$1,083m and an IRR of 41%, based on capacity of 408,000 tpa boric acid and 108,000 tpa SOP in three phases coming on stream over the next seven years.

- Fort Cady is a high margin project; based on conservative assumptions in the DFS the project is expected to generate EBITDA of US$345m in the first full year of operations, and EBITDA margins of 66%.

- Capex for Phase 1A is just US$37m; this should be financeable with debt, meaning minimum dilution to existing shareholders.

The Fort Cady project is located in the eastern part of the Mojave Desert in San Bernardino County, California. The project is located about 200 km northeast of Los Angeles, close to the town of Newberry Springs, and is about 50 km east of the city of Barstow. ABR acquired the project in May 2017. A Scoping Study was completed in December 2017, and a DFS in December 2018, just 19 months after the acquisition, and 17 months after the IPO. In January 2019, ABR released a low-capex version of the DFS, which is now considered ‘base case’.

The project has been led by ABR’s CEO, Mr Michael X. Schlumpberger. Mr Schlumpberger is a degreed Mining Engineer, and holds an MBA. He has more than 30 years’ experience in production, maintenance, engineering and management in mines and chemical plants. Mr Schlumpberger’s unique combination of experience has made him well suited for the Fort Cady project. Prior to joining ABR, Mr. Schlumperger developed the Highfield Resources (HFR.AX) project from the pre-feasibility stage, to the project being construction-ready. Prior to Highfield, he spent more than 20 years at PotashCorp, and worked in all three primary nutrients. At PotashCorp, he led the expansion of the largest potash mine, whilst the mine continued to produce. He served as Mill Superintendent for the phosphate operations, and also ran operations and maintenance organisations for the PotashCorp Ohio chemical plant producing ammonia, nitric acid, and other nitrogen products.

The Fort Cady project is a past-producing asset, with extensive historical development. The deposit was first discovered in 1964. Limited-scale solution mining was undertaken in 1981, and some 450 tonnes of boric acid were produced from pilot scale operations in 1987-1988. The project was fully approved for commercial scale operations in 1994. Extensive feasibility studies, detailed engineering and test works occurred in the late-1990s and early-2000s. This included a second pilot plant from 1996 to 2001 that used sulphuric acid as the leachate and produced some 2,300 tonnes of a synthetic colemanite product called ‘CadyCal’. All in all, more than US$60m has been spent on project development to date.

The DFS envisages production of 408,233 tpa of boric acid and 108,863 tpa of SOP coming on stream in three phases, with Phase 1 split into two parts. Construction of Phase 1A is expected to commence in 4Q19 after detailed engineering studies are completed, with first production scheduled for 4Q20. Phases 1B, 2 and 3 are expected to start two, four and six years after Phase 1A. The DFS is based on ABR reaching full capacity by mid-2026.
**Strong financials**

The project is expected to generate cumulative EBITDA of US$107m over the first three years. This figure includes Phase 1A, and the first year of Phase 1B when 1B is ramping up. In the first full year of production, the project is expected to generate EBITDA of US$345m. This equates to an EBITDA margin of 66%. The project boasts compelling financial metrics. The post-tax NPV$_{10}$ is US$1,083m. The IRR is ~41%.

Phase 1A, on a standalone basis, is financially attractive. It boasts an NPV$_{10}$ of US$225m, with an IRR of 58%, and an initial capex of just US$36.8m. In the first full year of production, Phase 1A is expected to generate EBITDA of US$27m.

**Figure 3: Key metrics by Phase**

<table>
<thead>
<tr>
<th></th>
<th>NPV$_{10}$</th>
<th>IRR</th>
<th>EBITDA, first full year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US$ m</td>
<td>%</td>
<td>US$ m</td>
</tr>
<tr>
<td>Phase 1A</td>
<td>225</td>
<td>58%</td>
<td>27</td>
</tr>
<tr>
<td>Phases 1A and 1B</td>
<td>385</td>
<td>36%</td>
<td>60</td>
</tr>
<tr>
<td>Phases 1 and 2</td>
<td>854</td>
<td>40%</td>
<td>192</td>
</tr>
<tr>
<td>Full project (Phases 1, 2 and 3)</td>
<td>1,083</td>
<td>41%</td>
<td>345</td>
</tr>
</tbody>
</table>

Source: ABR, DFS, January 2019

**Substantial reduction in initial capex**

The January 2019 DFS set out a plan to substantially reduce the initial capex of the project from US$138m in the December 2018 DFS to just US$37m. Essentially this was achieved by delaying the ramp-up of the boric acid plant. ABR now plans to run a smaller-scale commercial boric acid operation before the main build out of boric acid capacity.

The plan to split the former Phase 1 into Phases 1A and 1B has two obvious advantages. One is that it very substantially reduces the initial capex of the project to a point where ABR can reasonably look to finance the project with debt. This should make raising the financing easier, and should minimise the level of share dilution to existing investors. Another is that running a smaller scale boric acid plant is a valuable risk mitigation exercise. This will lower the technical and engineering risks in the build out of more substantial capacity in subsequent phases, and may result in lower capex and operating costs.

**Figure 4: Capex and production for each phase**

<table>
<thead>
<tr>
<th>Boric acid</th>
<th>SOP</th>
<th>Capex DFS Dec 2018</th>
<th>Capex Enhanced, Jan 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tonnes</td>
<td>SOP Tonnes</td>
<td>US$ 000s</td>
</tr>
<tr>
<td>Phase 1A</td>
<td>5,443</td>
<td>36,287</td>
<td>138,219</td>
</tr>
<tr>
<td>Phase 1B</td>
<td>76,204</td>
<td>-</td>
<td>111,375</td>
</tr>
<tr>
<td>Phase 2</td>
<td>163,293</td>
<td>36,287</td>
<td>191,442</td>
</tr>
<tr>
<td>Phase 3</td>
<td>163,293</td>
<td>36,287</td>
<td>186,549</td>
</tr>
<tr>
<td>Total</td>
<td>408,233</td>
<td>108,861</td>
<td>516,211</td>
</tr>
</tbody>
</table>

Source: ABR, DFS, December 2018 and January 2019
Although the initial capex of Phase 1A is significantly lower, the total project capex is expected to rise by ~US$10m. Most of this relates to the Phase 1A boric acid plant, which is in addition to the original plan. Once Phase 1B is up and running, the Phase 1A boric acid plant will be decommissioned, and used for other optimisation and engineering testing.

In the DFS (January 2019) the company essentially disclosed one lump sum for the boric acid plant, called ‘PLS (pregnant leach solution) recovery and clarification’. This includes the solvent extraction, crystallisation, gypsum, drying and other equipment necessary for Phase 1A. The advantage of lumping this altogether in the disclosure is that the additional capex costs for Phase 1A are clear, as is the fact that capex for Phase 1B (82,000 tpa boric acid) is unchanged.

**Figure 5: Initial capex breakdown**

<table>
<thead>
<tr>
<th></th>
<th>Phase 1A</th>
<th>Phase 1B</th>
<th>Total Phase 1</th>
<th>Phase 1 DFS, Dec 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enhanced DFS US$ 000s</td>
<td>Enhanced DFS US$ 000s</td>
<td>Enhanced DFS US$ 000s</td>
<td>DFS, Dec 2018 US$ 000s</td>
</tr>
<tr>
<td>Wellfield costs</td>
<td>1,800</td>
<td>3,391</td>
<td>5,191</td>
<td>3,391</td>
</tr>
<tr>
<td>PLS recovery and clarification</td>
<td>9,328</td>
<td>2,177</td>
<td>11,505</td>
<td>2,177</td>
</tr>
<tr>
<td>Solvent extraction</td>
<td>-</td>
<td>8,272</td>
<td>8,272</td>
<td>-</td>
</tr>
<tr>
<td>Crystallisation</td>
<td>-</td>
<td>7,071</td>
<td>7,071</td>
<td>-</td>
</tr>
<tr>
<td>Gypsum</td>
<td>-</td>
<td>2,958</td>
<td>2,958</td>
<td>-</td>
</tr>
<tr>
<td>Drying</td>
<td>-</td>
<td>8,366</td>
<td>8,366</td>
<td>-</td>
</tr>
<tr>
<td>Zero liquid discharge</td>
<td>2,300</td>
<td>3,806</td>
<td>6,106</td>
<td>3,806</td>
</tr>
<tr>
<td>Mannheim</td>
<td>14,488</td>
<td>-</td>
<td>14,488</td>
<td>-</td>
</tr>
<tr>
<td>Cogeneration facility</td>
<td>-</td>
<td>10,022</td>
<td>10,022</td>
<td>-</td>
</tr>
<tr>
<td>Other equipment costs</td>
<td>223</td>
<td>6,013</td>
<td>6,236</td>
<td>6,013</td>
</tr>
<tr>
<td><strong>Total equipment costs</strong></td>
<td><strong>28,139</strong></td>
<td><strong>52,077</strong></td>
<td><strong>80,216</strong></td>
<td><strong>66,565</strong></td>
</tr>
<tr>
<td>Process plant buildings</td>
<td>1,000</td>
<td>8,319</td>
<td>9,319</td>
<td>8,319</td>
</tr>
<tr>
<td>Production wells</td>
<td>-</td>
<td>12,811</td>
<td>12,811</td>
<td>12,811</td>
</tr>
<tr>
<td>EPCM</td>
<td>1,799</td>
<td>5,492</td>
<td>7,291</td>
<td>6,827</td>
</tr>
<tr>
<td>Other capex costs</td>
<td>2,731</td>
<td>19,864</td>
<td>22,595</td>
<td>26,341</td>
</tr>
<tr>
<td>Contingency</td>
<td>3,164</td>
<td>12,811</td>
<td>15,975</td>
<td>15,901</td>
</tr>
<tr>
<td><strong>Total capex</strong></td>
<td><strong>36,834</strong></td>
<td><strong>111,373</strong></td>
<td><strong>148,207</strong></td>
<td><strong>138,219</strong></td>
</tr>
</tbody>
</table>

Source: ABR, DFS, December 2018 and January 2019

Phase 1A is expected to generate EBITDA of ~US$54m in the first two years of operations. This is not sufficient to fund the capex requirement of Phase 1B. Once Phase 1A is up and running, and the company is generating cash flow, ABR plans to seek additional debt financing to complete Phase 1B. The company will probably need to raise an additional US$80m or so (Phase 1B capex is US$111m, of which a portion will be financed by cash flows from Phase 1A). By this stage, the company will already be in production, so this debt is likely to be cheaper than the funding for Phase 1A. Phases 2 and 3 are expected to be fully financed out of operating cash flows.

Taking the Phase 1A capex of US$37m and assuming a further US$80m is raised for Phase 1B, an ‘adjusted’ initial capex figure for Phases 1A and 1B together would be ~US$117m. Based on this figure the NPV to initial capex is more than 9x, which compares favourably to other projects.
The ramp-up schedule

In the January DFS, Phase 1A is expected to come on stream in 4Q20. Phase 1B is expected to come on stream two years later, in 4Q22. Phases 2 and 3 are expected to come on stream in 4Q24 and 4Q26. There is a general assumption in the DFS that new plant operates at 60% of full capacity for six months before reaching full capacity. This is fair for the boric acid business where new wells are being drilled, but for SOP this could turn out to be conservative; the Mannheim process is well understood.

In the first two years of the project, revenues will be driven by sales of SOP, and to a lesser degree, hydrochloric acid. The SOP plant will throw off more hydrochloric acid than the boric acid facility will be able to use. ABR will sell this excess hydrochloric acid into the US market. In 2020 and 2021, about 90% of revenues will come from SOP (61%) and hydrochloric acid (29%), but this will drop to 37% when Phase 2 (boric acid) ramps up. When the project is fully ramped up (all three phases,) it is expected that almost 80% of revenues will come from sales of boric acid.

Taking all three phases together, the SOP operations are designed to generate sufficient hydrochloric acid to fulfil the raw material requirement for the boric acid plant. As each phase is ramped up, less excess hydrochloric acid will be generated until by Phase 3, the project is roughly in balance with no excess. By this stage, and as currently scheduled, the company will have to buy some quantity of hydrochloric acid to fulfil its requirement, though there is plenty of scope for capacities to be tweaked before then.

Supplying heat to the injection solution (4% hydrochloric acid solution) improves the solubility of the ore body and thus the boric acid recovery rate. The DFS is based on a head grade recovery of 3.7% boric acid by weight. Given that these grades were achieved during pilot plant operations by Mountain State Minerals in 1986-1987 without the use of heat, this looks overly conservative. A head grade of 5% boric acid would result in 35% more boric acid being recovered. (See Appendix 2 for the processing history at Fort Cady).
Figure 6: Boric acid production, tonnes 000s

Source: ABR, DFS January 2019

Figure 7: SOP production, tonnes 000s

Source: ABR, DFS January 2019

Figure 8: Revenues by product, US$ m

Source: ABR, DFS January 2019

Figure 9: Revenues breakdown by product

Source: ABR, DFS January 2019

Figure 10: Hydrochloric acid, tonnes 000s

Source ABR, Orior Capital estimates

Figure 11: EBITDA, US$ m

Source ABR, Orior Capital estimates
Low operating costs

With Phase 1A targeting SOP capacity of ~36,000 tpa and boric acid capacity of 5,443 tpa, the operating costs for Phase 1A have been stated in terms of costs per tonne of SOP. With the benefit of by-product credits for boric acid, and especially hydrochloric acid, this brings down the C1 costs for SOP to below US$100/t. This highlights the robust profitability of Phase 1A; management estimates that SOP prices are more than US$700/t in the local California market.

Figure 12: SOP operating costs for Phase 1A

<table>
<thead>
<tr>
<th></th>
<th>US$/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumables</td>
<td>432</td>
</tr>
<tr>
<td>Labour</td>
<td>61</td>
</tr>
<tr>
<td>Maintenance</td>
<td>34</td>
</tr>
<tr>
<td>Others</td>
<td>28</td>
</tr>
<tr>
<td>Hydrochloric acid credits</td>
<td>(348)</td>
</tr>
<tr>
<td>Boric acid credits</td>
<td>(120)</td>
</tr>
<tr>
<td>C1 costs</td>
<td>86</td>
</tr>
<tr>
<td>Total operating costs</td>
<td>144</td>
</tr>
</tbody>
</table>

Source: ABR, DFS January 2019

For subsequent phases, the operating costs are as set out in the December 2018 DFS. Net of by-product credits, boric acid C1 costs are expected to be US$113/t in Phase 1 (Phase 1A and 1B combined), and US$149/t by Phase 3. This compares to a boric acid price of US$800/t.

Figure 13: Boric acid operating costs for Phases 1, 2 and 3

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>US$/t boric acid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumables</td>
<td>272</td>
<td>215</td>
<td>204</td>
</tr>
<tr>
<td>Labour</td>
<td>102</td>
<td>54</td>
<td>36</td>
</tr>
<tr>
<td>Maintenance</td>
<td>58</td>
<td>54</td>
<td>53</td>
</tr>
<tr>
<td>Utilities</td>
<td>44</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Others</td>
<td>20</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>SOP credits</td>
<td>(322)</td>
<td>(215)</td>
<td>(193)</td>
</tr>
<tr>
<td>Hydrochloric acid credits</td>
<td>(60)</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td>C1 costs</td>
<td>113</td>
<td>163</td>
<td>149</td>
</tr>
<tr>
<td>Total operating costs</td>
<td>217</td>
<td>250</td>
<td>231</td>
</tr>
</tbody>
</table>

Source: ABR, DFS December 2018

Figure 14: Other key assumptions used in the DFS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine life - Phase 1 only</td>
<td>Years</td>
<td>80</td>
</tr>
<tr>
<td>Mine life - Phases 1 and 2 only</td>
<td>Years</td>
<td>30</td>
</tr>
<tr>
<td>Mine life - Phases 1, 2 and 3</td>
<td>Years</td>
<td>21</td>
</tr>
<tr>
<td>Boric acid price</td>
<td>US$/t</td>
<td>800</td>
</tr>
<tr>
<td>SOP price</td>
<td>US$/t</td>
<td>725</td>
</tr>
<tr>
<td>Hydrochloric acid price</td>
<td>US$/t</td>
<td>276</td>
</tr>
<tr>
<td>Sulphuric acid price</td>
<td>US$/t</td>
<td>182</td>
</tr>
<tr>
<td>Muriate of potash (MOP) price</td>
<td>US$/t</td>
<td>298</td>
</tr>
<tr>
<td>Escalation of costs and revenues</td>
<td>US$/t</td>
<td>3%</td>
</tr>
<tr>
<td>Federal tax rate</td>
<td>%</td>
<td>22%</td>
</tr>
<tr>
<td>State tax rate</td>
<td>%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Source: ABR, DFS December 2018
Price sensitivity

The DFS is based on a boric acid price of US$800/t. This is based on discussions with industry experts and distributors. This seems conservative compared to current quoted prices for Chinese 99% calcium borates which are US$900/t to US$1,000/t fob China. Refined sodium tetraborate (borax) decahydrate (Na₂B₄O₇·10H₂O) prices are currently quoted at US$820/t to US$950/t for 99.5%+ quality material. ABR has assumed an SOP price US$725/t.

Based on the December 2018 DFS, a 15% increase in the boric acid price from US$800/t to US$920/t would raise the post-tax NPV₁₀ by 23% to US$1,532m. The project is less sensitive to SOP prices. A 15% increase in the SOP price from US$725/t to US$834/t would raise the post-tax NPV₁₀ by 6% to US$1,318m.

Substantial resources

Fort Cady hosts the largest colemanite resource in the US. The project has total resources (measured, indicated and inferred) of 120m tonnes at an average grade of 6.5% boric oxide (B₂O₃) (and a 5% cut-off grade), for a contained boric oxide resource of 7.84m tonnes. The resource has an average grade of 11.6% boric acid (H₃BO₃) for a contained boric acid resource of 13.9m tonnes.

In total, 76.0m tonnes, representing 63% of the resource is owned or controlled by Fort Cady California Corp. (FCCC), a wholly owned subsidiary of ABR. Roughly 86.6m tonnes, or 72% of the resource occurs within the approved Operating Permit region that was awarded in 1994, and is approved for commercial-scale operations. Some 42.2m tonnes, 35% of the total resource that occurs within Operating Permit region is fully owned by ABR.

The resource is based on 33 holes drilled by Duval, a previous owner of the project in 1977-1981, and an additional 14 holes that ABR has completed since purchasing the project in May 2017 aimed at confirming and expanding the resource.

There are some power lines traversing the project area. Of the total resource, 44.4m tonnes (37%) is contained within the Southern California Edison (SCE) Land Title (see Appendix 2). The SCE land title occurs fully within the Operating Permit area which bestows all mining rights of the deposit to FCCC.

Boric oxide (B₂O₃) has a molecular weight of 69.617 g/mol. Boric acid (H₃BO₃) has a molecular weight of 61.833 g/mol. Two mols of boric acid (to get two boron atoms) weighs 123.666 g. The conversion factor between boric acid and boric oxide is 123.666/69.617=1.773.
### Figure 15: Fort Cady mineral resources

<table>
<thead>
<tr>
<th></th>
<th>Tonnage (tonnes m)</th>
<th>B₂O₃ (Weight %)</th>
<th>H₃BO₃ (Weight %)</th>
<th>Li (ppm)</th>
<th>B₂O₃ (tonnes m)</th>
<th>H₃BO₃ (tonnes m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total measured resources</strong></td>
<td>38.9</td>
<td>6.70</td>
<td>11.9</td>
<td>379</td>
<td>2.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>33.5</td>
<td>6.67</td>
<td>11.9</td>
<td>382</td>
<td>2.2</td>
<td>4.0</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>5.4</td>
<td>6.91</td>
<td>12.3</td>
<td>362</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total indicated resources</strong></td>
<td>19.7</td>
<td>6.40</td>
<td>11.4</td>
<td>343</td>
<td>1.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>5.9</td>
<td>6.09</td>
<td>10.8</td>
<td>359</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>13.8</td>
<td>6.53</td>
<td>1.6</td>
<td>336</td>
<td>0.9</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Total inferred resource</strong></td>
<td>61.9</td>
<td>6.43</td>
<td>11.4</td>
<td>322</td>
<td>4.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>2.8</td>
<td>5.43</td>
<td>9.7</td>
<td>292</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>14.6</td>
<td>7.06</td>
<td>12.5</td>
<td>367</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>44.4</td>
<td>6.29</td>
<td>11.2</td>
<td>309</td>
<td>2.8</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Total measured, indicated and inferred</strong></td>
<td>120.4</td>
<td>6.51</td>
<td>11.6</td>
<td>344</td>
<td>7.8</td>
<td>13.9</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>42.2</td>
<td>6.51</td>
<td>11.6</td>
<td>373</td>
<td>2.8</td>
<td>4.9</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>33.8</td>
<td>6.82</td>
<td>12.1</td>
<td>354</td>
<td>2.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>44.4</td>
<td>6.29</td>
<td>11.2</td>
<td>309</td>
<td>2.8</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Source: ABR, DFS December 2018

For the purposes of the DFS, ABR has excluded resources that lie within the SCE land corridor. This reduces the resources from 120m tonnes to about 95m tonnes. No part of the mineral reserve is contained within this land corridor.

Management believes there may be an opportunity to relocate power lines associated with the SCE land corridor. This could potentially add another 5 years to the proposed mine life.

### Figure 16: Fort Cady mineral resources, excluding Southern California Edison right of way area

<table>
<thead>
<tr>
<th></th>
<th>Tonnage (tonnes m)</th>
<th>B₂O₃ (Weight %)</th>
<th>H₃BO₃ (Weight %)</th>
<th>Li (ppm)</th>
<th>B₂O₃ (tonnes m)</th>
<th>H₃BO₃ (tonnes m)</th>
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<td>2.6</td>
<td>4.6</td>
</tr>
<tr>
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<td>6.67</td>
<td>11.9</td>
<td>382</td>
<td>2.2</td>
<td>4.0</td>
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<td>5.4</td>
<td>6.91</td>
<td>12.3</td>
<td>362</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total indicated resources</strong></td>
<td>19.7</td>
<td>6.40</td>
<td>11.4</td>
<td>343</td>
<td>1.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>5.9</td>
<td>6.09</td>
<td>10.8</td>
<td>359</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>13.8</td>
<td>6.53</td>
<td>1.6</td>
<td>336</td>
<td>0.9</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Total inferred resource</strong></td>
<td>36.1</td>
<td>6.40</td>
<td>11.4</td>
<td>331</td>
<td>4.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>2.8</td>
<td>5.43</td>
<td>9.7</td>
<td>292</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>14.6</td>
<td>7.06</td>
<td>12.5</td>
<td>367</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>18.6</td>
<td>6.02</td>
<td>10.7</td>
<td>309</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total measured, indicated and inferred</strong></td>
<td>94.6</td>
<td>6.52</td>
<td>11.6</td>
<td>353</td>
<td>7.8</td>
<td>13.9</td>
</tr>
<tr>
<td>Elementis, FCCC</td>
<td>42.2</td>
<td>6.51</td>
<td>11.6</td>
<td>373</td>
<td>2.8</td>
<td>4.9</td>
</tr>
<tr>
<td>FCCC surface, State of CA minerals</td>
<td>33.8</td>
<td>6.82</td>
<td>12.1</td>
<td>354</td>
<td>2.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>18.6</td>
<td>6.29</td>
<td>11.2</td>
<td>309</td>
<td>2.8</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Source: ABR, DFS December 2018
Next steps

The next steps revolve around detailed engineering studies for phase 1A, and progressing financing discussions to the point where phase 1A is financed. Management aims to have financing in place in time to allow construction of Phase 1A to commence in 4Q19. This will allow Phase 1A to commence operations in 4Q20. ABR is also looking at ways to decouple the SOP operation from the broader operation that should provide additional financing options.

The Fort Cady project is fully approved for construction, but needs to file the SWPPP (Stormwater pollution prevention plan). This is being completed and submission is expected in early 2Q19. The company needs to secure two permits before Phase 1 mining activities can commence. These are the Air Quality permit, which management expects to be awarded in 2Q19, and the Underground Injection Control permit, which is expected in 3Q19. Drawing down financing, will presumably be conditional upon gaining these permits.

For Phases 2 and 3, ABR will need to demonstrate adequate water supply, and to modify its Plan of Operations to reflect this.

The Fort Cady project contains some reasonable grades of lithium; the measured resource has an average grade of 379 ppm lithium, and the total resource has an average grade of 353 ppm. It is expected that lithium grades will increase in the brine as the brine is recycled through the formation. ABR is examining the feasibility of extracting lithium as a by-product from the gypsum circuit using filtration. Lithium extraction is not assumed in the DFS, and probably won’t be thoroughly evaluated until Phase 2 comes on stream (2024).
Valuations: Looks like a 10-bagger

- ABR looks astonishingly cheap at about 2% of NPV
- Based on ABR being fully financed, in development, and a year or less from cash flows, the shares could trade at 7-14x the current share price
- Longer-term, ABR could be worth as much as A$4.6bn to a major industrial minerals or speciality fertiliser group; that is 150x the current market cap.

Market cap versus NPV

ABR looks incredibly cheap in absolute terms. The current market capitalisation (US$21m) is about 2% of the lower capex scenario NPV of US$1,083m. This cheap valuation reflects several factors:

- Fort Cady is a superb project with a high NPV
- The DFS studies were published in December 2018 and January 2019, and have probably not been fully absorbed by the market
- A lack of understanding of the borates market amongst investors
- The project is not yet fully approved or financed
- The terrible current market for junior mining companies

NPV based valuations

As an admittedly rather broad rule of thumb, projects that are one year or less away from generating cash flows, fully financed, and fully approved can tend to attract EV valuations of 30% to 50% of NPV. This is a broad range, and depends on a variety of factors including jurisdiction, scale, the perception of management, how ‘hot’ the commodity is at the time, and others. At this stage, ABR is probably about two years away from first cash flows. Construction of Phase 1 is expected to commence in 4Q19, with production expected to ramp-up in 4Q20. Thus, a year from now (1Q20) when ABR is nearer cash flow, the company could trade at an EV of US$325m to US$542m (30% to 50% of NPV).

Assuming total initial capital (including working capital) of US$50m for Phase 1A, a further US$80m for Phase 1B, debt financing, with 50m warrants issued as a Phase 1A incentive to funds fully converted at A$0.50 per share, and a fair EV valuation of 30-50% of NPV, ABR shares could be valued at A$1.10 to A$2.21 per share, roughly 7-14x the current share price. This is somewhat broad-brushed, and it is a wide range, but it highlights how undervalued the shares are now.

It also highlights the value of the lower capex path to production. Whilst the boric acid plant will ramp-up later than envisaged in the December 2018 DFS, the combination of a substantial reduction in initial capex, and lower level of likely equity dilution stand to benefit shareholders. Importantly, it should make raising the money easier.
Valuations based on the December 2018 DFS

While the January 2019 DFS is the base case scenario for management’s funding plans, and hence for valuations, it is also worth exploring potential valuations based on the December 2018 DFS. The December 2018 DFS boasted a post-tax, unlevered NPV of US$1.25bn, with initial capex of US$138.2m. Financing this amount will mean some degree of equity dilution. Assuming a total initial capital requirement (including working capital) of US$160m, 80:20 debt-to-equity funding, and equity being issued at A$0.40 to A$0.50 per share, ABR would need to issue between 90m and 112m new shares. This would increase the fully diluted shares outstanding from 222m now, to between 312m to 334m shares. The company would have US$128m (A$179m) of debt.

Based on these figures, ABR shares could be worth A$1.04 to A$2.23 a year from now. That is, on a one year view, based on the higher initial capex and faster ramp up scenario, the shares could be worth 6.5-14x the current share price, similar to the valuation under the January 2019 DFS above.

In terms of sensitivity to the debt assumption, using a debt-to-equity assumption of 70:30 suggests a valuation range to A$0.94 to A$2.02, and a debt-to-equity assumption of 60:40 suggests a valuation range to A$0.88 to A$1.85.

Is it feasible to issue new shares at a premium to today’s share price? Yes. First, the current share price (market cap. ~2% of NPV) does not reflect the quality of the project. Second, like many junior mining companies, ABR’s shares are not very liquid. Only about 7.3m shares have traded in the past 3 months, turning over less than US$1.0m. Illiquid shares tend of get punished in weak markets (such as 2018) but do well when things turn. A little renewed interest in the stock, seems likely to have a significant impact on the share price. On this basis, issuing shares at a premium to today’s price is entirely possible.

Valuations in either case are similar. The point is that although the NPV in the lower capex version of DFS is lower (because the boric acid capacity comes on later), this is offset by the lower expected dilution. ABR looks massively undervalued either way.
Industrial/technical minerals peers

It is difficult to find direct peers in borates because the market is small, and there are few producers. In 2017, the global boric oxide \( (\text{B}_2\text{O}_3) \) market was \(~2.3\text{m} \) tonnes, of which about 80% of supply came from Eti Maden in Turkey (not listed) and Rio Tinto, for which borates is a relatively minor part of the business. One company that might be compared is Ioneer (INR.AX), which is developing the Rhyolite Ridge project in Nevada. Rhyolite Ridge is a mixed lithium-boric acid project. Ioneer published a Pre-Feasibility Study for the project in October, 2018 in which it disclosed an unlevered post-tax NPV\(_{10}\) of US$1,104m, and an initial capex requirement of US$599.5m. The project is expected to produce 20,200 tpa lithium carbonate and 173,000 tpa boric acid. At NPV\(_{10}\), both companies have similar NPVs (about US$1.1bn), yet ABR has:

- A more advanced (DFS) level project
- A lower market cap. to NPV ratio
- A higher NPV to initial capex requirement
Figure 19: ABR compared to Ioneer

Source: Company data, Orior Capital estimates

Industrial minerals companies diversified across minerals

Looking beyond borates, there are a number of listed industrial minerals companies. This includes companies such as Imerys (NK.PA), Albemarle (ALB), Minerals Technologies (MTX), Sociedad Química y Minera de Chile (SQM), Compass Minerals (CMP) and others. Many industrial minerals markets, like borates, are fairly small. The global silica sand market was ~US$11.3bn in 2017, but the global markets for kaolin, fluor spar and bentonite were ~US$5.0bn, ~US$2.0bn and ~US$1.1bn respectively. The global potash fertilisers market was ~US$18.5bn in 2017, but the market for potassium sulphates was ~US$3.7bn. As a result, these markets have tended to become consolidated, and the main players are diversified across a range of minerals.

Longer-term, the focus will be on earnings multiples

Looking at a broad range of eight of these companies, active across a range of minerals, geographies, and listed in different markets, the group is trading at ~9.5x (range 6.4x to 12.0x) trailing EV/EBITDA. PE-based valuations are trickier; the range is much wider. Importantly, ABR has a long-life project which, once up and running, should justify these types of valuations.

Applying the bottom end of the range, and the average, to ABR’s expected annual EBITDA of US$345m in the first full year of production (mid-2027 to mid-2028) suggests an EV valuation of US$2,208m (bottom end) to US$3,278m (average). This is 2.0x to 3.0x NPV₁₀. This might seem high now, but well into the project, ABR could be throwing off cash earnings after tax of more than US$200m pa.

Assuming this is achievable in say, eight years’ time, and investors demand a 25% pa return (this is still junior mining), we can discount this valuation range back to get to a current valuation range of US$370m to US$550m. This is 34% to 51% of NPV.
Sulphate of potassium companies

There are several budding SOP companies listed on the ASX. ABR aims to produce SOP primarily as a means to generate hydrochloric acid for the boric acid operations, and because there is ready supply of sulphuric acid close by in Nevada. In terms of expected annual revenues, ABR is likely to generate 19% of revenues from SOP and 79% from boric acid, with the SOP revenues treated as a by-product once the boric acid capacity is ramped-up. As a result, the ASX-listed SOP juniors, whose primary aim is to supply the SOP market are not viewed as being directly comparable to ABR.
Significant Chinese partners

- Cooperation agreements with two Chinese partners could potentially provide a path to market
- China’s rapid economic growth and rising middle class will continue to underpin strong demand growth for borates
- Sinochem Group and Sinomach are both substantial groups and Fortune Global 500 companies

In May 2018, ABR signed two cooperation agreements with Chinese partners. The first was with Sinochem Hebei Corp, a subsidiary of China’s state-owned Sinochem Group. The second was with China National Chemical Fiber Corp, a subsidiary of China National Machinery Industry Corp (known as “Sinomach” for short). Both Sinochem Group and Sinomach are substantial groups and Fortune Global 500 companies.

It is no surprise that major Chinese groups were quick off the mark. China’s rapid GDP growth, and rising middle class suggests that boron demand in China will remain strong. That two of China’s largest and most established state-owned enterprises entered into these agreements is a testament to the Fort Cady project, the strategic need for new sources of borates, and also underscores the robust outlook for boron in China.

Sinochem Group
Sinochem Group is one of China’s four largest state-owned oil companies. It is China’s leading chemical service provider and China’s largest agricultural inputs company, supplying fertilisers, seed and agrochemicals. In 2018, Sinochem Group was ranked 98th in the Fortune Global 500. The group employs more than 50,000 people worldwide. Sinochem plays a key role in China for the supply and distribution of borates.

Sinomach Group
Sinomach Group, is a globally diversified, industrial equipment group. Its primary businesses are in mechanical equipment, project contracting, trade and services, and finance. It is active across a wide range of industries including aeronautics and astronautics, transportation, environmental engineering, and agriculture and forestry. In 2018, Sinomach was ranked 334th in the Fortune Global 500. China National Chemical Fiber Corp. (“CNCFC”) focuses on trading of natural fibres, chemical fibres, chemical fibre feedstock, chemicals and agriculture products.

For comparison, Rio Tinto is ranked 278th, and BHP 296th in the 2018 Fortune 500.
Tremendous strategic potential

- With the only colemanite resource in the US, and as only the second producer of SOP in the US, ABR has multiple strategic possibilities
- A number of major US and European based industrial minerals and speciality fertiliser companies stand to benefit from a tie-up with ABR
- ABR could partner with a glass or glass fibre maker, secure offtake financing with an existing Chinese partner, or look to finance the SOP project separately

Tremendous potential for strategic partnerships

Given the widespread M&A activity in both industrial minerals and speciality fertilisers sectors over the past few years, it seems highly likely ABR will attract attention. A number of industrial minerals and speciality fertiliser companies would stand to benefit from a tie-up with ABR. This may mean the company has financing options beyond the more obvious debt and equity routes. It may be possible to finance the borates and SOP operations separately. From ABR’s perspective, gaining access to US distribution would be valuable. In this section, several companies are highlighted, both potential partners and those that at first glance may seem less likely. None of this is to suggest that a deal is on the cards; it’s a thought process aimed at outlining possibilities.

Several factors suggest that ABR would make a highly valuable strategic partner:

- **The Fort Cady project has terrific earnings potential**: expected EBITDA is US$345m in the first full year of operations. To put this into context, Compass Minerals, the only producer of SOP in the US achieved consolidated EBITDA of US$273m in 2018. Belgium group, Tessenderlo, which is a global Top 5 SOP producer, achieved €183m in recurring EBITDA, in 2018.

- **Fort Cady hosts the only colemanite resource in the US. This is strategically important**: it is the only large-scale alternative source of supply to Eti Maden in Turkey (which currently enjoys a near-monopoly). Calcium based borates are essential in some industries, including for example the glass used in flat panels.

- **ABR will be only the second supplier of SOP in the US** (after Compass Minerals). SOP is an important crop nutrient for crops that are chloride sensitive, of high value, and which have high sulphur requirements. SOP is seeing increasing use in areas with sandy soils, such as in the Pacific Coast states. The US SOP market is estimated to be growing at ~5% pa.

- **Excellent jurisdiction. The US.**

A range of 14 US and European industrial minerals and speciality fertilizer companies are highlighted. Existing SOP producers seem to be obvious candidates for some type of cooperation. Both Compass Minerals and Tessenderlo have strong US distribution. K+S Group is Europe’s largest potash company. It has plans to substantially raise profitability over the next decade, and aims to move into speciality fertilisers. Also, SQM, better known as a lithium producer, derived 22% of gross profit from speciality plant nutrition in 2018.
Borates and boron are such pervasive minerals in modern society, that any one of a number of up- or downstream industrial minerals companies could make effective partners. French group, Imerys, is the global leader, and highly acquisitive. Borates are potentially synergistic with various applications that Imerys supplies into. Private US industrial group, Koch Industries produces glass, and fibreglass, the two biggest segments of borates demand. Rio Tinto owns the US Borax project in California, and the Jadarite project in Serbia. Fort Cady would be local, substantial, and near-term.

**In short, there is tremendous potential for strategic partnerships.**

**Figure 22: US and European companies**

<table>
<thead>
<tr>
<th>Company</th>
<th>Code</th>
<th>Market cap. US$ m</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compass</td>
<td>CMP</td>
<td>1,790</td>
<td>The only SOP producer in the US</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Acquired South American plant nutrition business in 2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ABR is significant in terms of expected earnings</td>
</tr>
<tr>
<td>Tessenderlo</td>
<td>TESB.BR</td>
<td>1,471</td>
<td>Produces SOP in Europe, and has global distribution.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ABR is significant in terms of expected earnings</td>
</tr>
<tr>
<td>Rio Tinto Ventures</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Borates business an obvious fit given existing assets</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More flexible financing possible compared to Rio Tinto</td>
</tr>
<tr>
<td>K+S Group</td>
<td>SDF.F</td>
<td>3,671</td>
<td>Europe’s largest potash company</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Looking to aggressively expand earnings in Vision 2030</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stated aim to expand in speciality fertilisers</td>
</tr>
<tr>
<td>Imerys</td>
<td>NK.PA</td>
<td>4,370</td>
<td>Global leader in specialised industrial minerals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Very acquisitive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Borates business potentially synergistic</td>
</tr>
<tr>
<td>SQM</td>
<td>SQM</td>
<td>9,907</td>
<td>Known for lithium, but also global leader in potassium nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Has flexibility to produce MOP, SOP and KNO₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Has global distribution</td>
</tr>
<tr>
<td>Koch Industries</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Diversified private US-based industrials conglomerate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Borates potentially synergistic with glass and fibreglass</td>
</tr>
<tr>
<td>Intrepid Potash</td>
<td>IPI</td>
<td>455</td>
<td>Largest producer of potassium chloride (MOP) in the US</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Actively looking for high margin, accretive opportunities</td>
</tr>
<tr>
<td>Albemarle</td>
<td>ALB</td>
<td>8,947</td>
<td>Leading positions in lithium, bromine and refining catalysts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recent deal flow has focused on lithium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Potential downstream synergies in lithium, bromine and borates</td>
</tr>
<tr>
<td>Nutrien</td>
<td>NTR</td>
<td>32,466</td>
<td>World’s largest provider of crop nutrients</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Focused on integrating the PotashCorp and Agrium businesses</td>
</tr>
<tr>
<td>CF Industries</td>
<td>CF</td>
<td>8,976</td>
<td>Largest producer of ammonia and nitrogen globally</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Focused on core business and capital management</td>
</tr>
<tr>
<td>Yara International</td>
<td>YAR.OL</td>
<td>898</td>
<td>World’s largest producer of nitrates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Investing in SOP project in Ethiopia</td>
</tr>
<tr>
<td>Mosaic</td>
<td>MOS</td>
<td>10,762</td>
<td>Leading producer of MOP and phosphate fertilisers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Currently produces Potash-Boron product, Aspire</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Has no vertical integration of borates</td>
</tr>
<tr>
<td>Cargill</td>
<td>n.a.</td>
<td>n.a.</td>
<td>Leading positions in commodities, trading and risk management</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strong distribution via crop, seed and fertiliser products, services</td>
</tr>
</tbody>
</table>

**Source: Company data, Orior Capital estimates**
Compass Minerals

Current business profile
Compass Minerals (CMP) produces salt, plant nutrients and magnesium chloride for distribution primarily in North America. The company owns the world’s largest salt mine, located in Canada, the largest dedicated salt mine in the UK, and is a leading supplier of highway de-icing salt products into the North American and UK markets. Compass also owns a growing speciality plant nutrition business with operations in North and South America. It is the largest producer of SOP based fertilisers in the Western Hemisphere, and the only producer in the US. The company’s speciality plant nutrition products include a line of micronutrients that coat onto dry fertilizer, Wolf Trax™ DDP® Nutrients, and Protassium+® sulphate of potash. Compass has a current market cap. of US$1.8bn.

Earnings
Compass achieved revenues of US$1.5bn in 2018, and adjusted EBITDA of US$273m. The company is guiding for EBITDA of US$310m to US$350m in 2019 (company presentation, February 2019). It is seeing strong growth in its plant nutrition business with sales volumes up 11% YoY in 2018 in North America, and up 6% YoY in South America.

In 2018, the salt business accounted for 57% of group revenues and 63% of adjusted EBITDA. Not surprisingly, the business is highly seasonal, with revenues peaking typically in the March quarter. Compass aims to reduce its reliance on this seasonal business by expanding into plant nutrition.

Recent acquisitions, disposals and strategic partnerships
The South American plant nutrition business, Produquímica, was acquired in 2016. Produquímica is one of Brazil’s leading manufacturers and distributors of specialty plant nutrients. According to Compass Minerals, Produquímica operates two primary businesses – agricultural productivity and chemical solutions. The agricultural productivity division manufactures and distributes a broad offering of specialty plant nutrition solution-based products. These include micronutrients, controlled release fertilizers, and other specialty supplements used in direct soil and foliar applications, as well as through irrigation systems and for seed treatment. Produquímica also manufactures and markets specialty chemicals, primarily for the water treatment industry and for use in other industrial processes in Brazil.

Potential strategic fit with ABR
ABR has a current market cap. that is less than 2% that of Compass Minerals. Yet, at full production ABR is expected to generate EBITDA that is 1.5x what Compass Minerals achieved in 2018. Applying Compass Minerals’ current EV/EBITDA of 11.8x to ABR’s expected annual EBITDA once Fort Cady is fully up and running suggests that by 2026, Fort Cady could be worth US$4.1bn in EV to Compass Minerals.

There is also potential for some kind of tie-up in SOP. Compass would probably prefer some kind of arrangement rather than new competition, and ABR would benefit from distribution in the US.
Tessenderlo Group

Current business profile
Tessenderlo Group (TESB.BR) is a Belgian chemical company that is active in nutrition, agriculture, and water management. Tessenderlo Group is traded on Euronext Brussels, and has a current market cap. of US$1.5bn. The business is divided into three segments; Agro, which supplies crop nutrients, including SOP, and crop protection products; Bio-valorization, which processes animal by-products; and Industrial Solutions, which makes plastic piping, chemicals for water treatment and is involved in the recovery of industrial process liquids.

Tessenderlo produces SOP in Ham, Belgium. It is one of the top 5 global producers of SOP, and exports to more than 80 countries. The group makes SoluPotasse®, a premium soluble potassium sulphate product, and is the only company in the world that offers a foliar grade of SOP (applied to foliage), under the brand name K-Leaf®, for application on broad-acre crops.

Earnings
In 2017, Tessenderlo achieved nearly €1.7bn in revenues, and €183m in recurring EBITDA.

Recent acquisitions, disposals and strategic partnerships
Much of Tessenderlo’s recent M&A activity appears to have been aimed at divesting the group of non-core assets. In 2017, the group sold several businesses involved in pharmaceutical ingredients, chemicals businesses involved in PVC, chlor-alkali and organic chlorine, and its PVC building products business. In 2018, Tessenderlo bought the remaining 80% in T-Power NV, a gas-fired 425 MW power plant in Tessenderlo, Belgium for €313m.

As with Compass Minerals, there is potential for some kind of tie-up in SOP. Tessenderlo would gain US production or perhaps offtake, and ABR would gain US distribution.

Potential strategic fit with ABR
Given Tessenderlo’s existing SOP capacity in Europe, and global distribution there should be good synergies between Tessenderlo and ABR. ABR has a current market cap. that is less than 2% that of Tessenderlo. Yet, at full production ABR is expected to generate EBITDA that is 1.7x what Tessenderlo achieved in 2017. Applying Tessenderlo’s current EV/EBITDA of 8.1x to ABR’s expected full production EBITDA suggests that by 2026, Fort Cady could be worth US$2.8bn in EV to Tessenderlo.

Rio Tinto Ventures

Current business profile
Rio Tinto established Rio Tinto Ventures in 2017, as a new group within the Energy and Minerals Product Group. The idea is to identify, and ultimately acquire advanced projects (feasibility stage and beyond) and operating entities across a range of commodities not currently in Rio’s commodity portfolio, and which stand to benefit from long-term macro-economic trends such as urbanisation and disruptive technologies. Two trends that stand out as impacting commodities greatly are the advent of the electric vehicle and the development of new power storage technologies.

Whilst Ventures is still most likely to be an equity investor, the group has a more flexible approach to
financial structure, and can consider debt and other instruments.

**Potential strategic fit with ABR**

Rio Tinto Ventures seems like a natural partner for ABR. Rio Tinto already has interests in borates with its operating US Borax mine in California, and with its Jadar project in Serbia. Over the past few years, production at US Borax has stabilised. The Jadar project is a lithium-borates project. It contains one of the largest lithium deposits in the world, but will require substantial further investment to bring to fruition. Fort Cady could provide a new growth impetus in a rare and strategically important mineral, in a near term project, with low capex.

**K+S Group**

**Current business profile**

K+S Group (SDF.F) is a German chemical company, headquartered in Kassel. The group is the world’s largest salt producer and Europe’s largest producer of potash. K+S Group is active in agriculture, food, road safety (salt) and various products used in industrial processes. The group is listed on the Frankfurt stock exchange, and has a current market capitalisation of US$3.7bn.

In October 2018, K+S Group set out its “Vision 2030”, a strategy for growing the business over the next decade or so. This new focus is aimed at, among other things, achieving EBITDA of €3.0bn by 2030. K+S Group recognises that it is mainly perceived as a producer of potassium chloride (MOP) and salt, and that it is not recognised for its higher value-added products. Part of Vision 2030, is to reduce the group’s dependence on MOP, and on weather. In agriculture, K+S Group plans to expand its offering of speciality fertilisers.

**Earnings**

In 2017, revenues were €3.7bn, including potash and magnesium revenues of €1.7bn (47% of total), and salt revenues of €1.8bn (49%). In 2017, consolidated EBITDA was €577m, of which €269m came from potash and magnesium, and €325m came from salt.

**Recent acquisitions, disposals and strategic partnerships**

K+S Group has not been active in M&A recently. The acquisition of the US salt business, Morton Salt, was in 2009. In 2015, K+S Group fended off a hostile takeover bid from PotashCorp of Saskatchewan (now part of Nutrien). In 2017, K+S Group commissioned a new potash plant in Bethune, in the south of the Canadian province of Saskatchewan. The project was substantial, taking some five years to complete (K+S Group annual report, 2017). At the end of 2017, K+S Group had €4.2bn of net debt and in 2017, net debt/EBITDA was 7.2x.

**Potential strategic fit with ABR**

K+S Group has a stated aim to expand its portfolio of speciality fertiliser products, and is active in industrial products where there may be synergies with boron and borates. K+S Group potentially has a good strategic fit with ABR. ABR’s expected EBITDA in the first full year of operation is ~€282m (at current exchange rate). This is ~49% of K+S Group’s EBITDA in 2017, and 9% of targeted EBITDA in 2030.
Imerys

Current business profile
Imerys S.A (NK.PA) is a French multinational group headquartered in Paris. It is the world leader production and processing of specialised industrial materials. Imerys organises itself into two main divisions. The Performance Minerals division focuses on materials for the plastics, paints & coatings, filtration, ceramics, renewable energy, and paper & board industries in Europe, Middle East and Africa (EMEA), the Americas and Asia Pacific. The High-Temperature Materials & Solutions division focuses on serving the refractory, foundry, metal flow, abrasives, and building chemistry markets. Imerys has a current market cap. of US$4.4bn.

Earnings
In 2018, Imerys achieved consolidated revenues of €4.6bn and consolidated EBITDA of €793m.

Recent acquisitions, disposals and strategic partnerships
Many of the industrial minerals markets are fairly small. As a result, the industry leaders have tended to grow by acquiring new businesses. Imerys has been highly acquisitive over the past few years.

In 2015, Imerys acquired S&B, a global leader in bentonite (binders for foundry, sealing solutions, additives for drilling and functional additives), and the world leader in continuous casting fluxes for steel and in wollastonite (functional additives for polymers and paints). Imerys also bought the Precipitated Calcium Carbonate (PCC) division of Solvay, and the paper hydrous kaolin (PHK) business in the US from BASF.

In 2016 Imerys strengthened its position in natural graphite through a joint venture in Namibia (now on care and maintenance), acquired a specialty alumina business from Alteo, acquired SPAR, a North American monolithic refractory producer, mainly serving the petrochemical, power generation, cement and incineration industries, as well as Damolin, a Danish producer of mineral solutions based on bentonite and moler, a mineral with absorbent properties for oils and chemicals, animal feed and cat litter.

In 2017, Imerys completed the acquisition of Kerneos, the world leader in calcium aluminate-based high-performance binders, as well as several further bolt-on acquisitions.

Potential strategic fit with ABR
Boron and borates are used in a range of applications that Imerys already serves. The Fort Cady project seems congruent to Imerys’ existing business, and hosts a strategically important resource.

Sociedad Química y Minera

Current business profile
SQM is one of the largest lithium producers globally with lithium assets in Chile, Argentina, and with the Kidman Resources JV for Mt Holland, also in Australia. In addition, SQM is the global market leader in producing potassium nitrate (KNO₃) of natural origin. The company has 16 NPK (nitrate-phosphorus-potassium) plants globally, with a current capacity of 11.5m tpa. SQM is also active in potassium based fertilisers. It is a low-cost producer of MOP, and has the flexibility to produce MOP, SOP and KNO₃ depending on market demands. The group does not currently have any production
assets in the US. SQM has a current market cap. of US$9.9bn.

**Earnings**
SQM reported revenues for the 12 months to December 2018 of US$2.3bn, and adjusted EBITDA of US$911m. The lithium business contributed about 30% to revenues, and about 55% to gross profit. The speciality fertilisers business contributed 34% of revenues, and about 22% to gross profit.

**Recent acquisitions, disposals and strategic partnerships**
In May 2018, Chinese company Tianqi Lithium Industries (002466.SZ) announced that it planned to buy a 23.77% stake in SQM for US$4.1bn, from Canadian fertiliser producer Nutrien. The deal was completed in December 2018.

In 2018, SQM announced a 50:50 joint venture with ASX listed Kidman resources for the Mt Holland lithium project. The project hosts one of the world’s most significant hard rock lithium deposits. The project is currently in the feasibility study stage, with estimated commissioning dates of 2020 for spodumene concentrate and 2021 for lithium hydroxide.

**Potential strategic fit with ABR**
Potentially, both the borates and SOP businesses could be of interest to SQM. Lithium and boron are used together in lithium-based batteries. There may be downstream synergies. SQM owns a substantial speciality fertiliser business: Fort Cady could provide access to US based assets, and a meaningful presence in SOP.

**Koch Industries**

**Current business profile**
Koch Industries is a private multinational group based in Wichita, Kansas. It is involved in a diverse range of activities including petroleum, chemicals, energy, fibre, minerals, fertilizers, pulp and paper, chemical technology equipment, ranching, finance, commodities trading, and investing. Koch owns Invista (fibres and resins), Georgia-Pacific (pulp and paper), Molex (electronic, electrical and fibre-optic interconnection systems), Flint Hills Resources (refining, chemicals, polymers and biofuels), Koch Pipeline, Koch Fertilizer, Koch Minerals, Matador Cattle Company, and Guardian Industries (float glass, fabricated glass products, fibreglass insulation and building materials). All in all, the firm employs 120,000 people in 60 countries, with about half of its business in the United States.

**Earnings**
Koch Industries is believed to be the second largest privately held company in the United States after Cargill, with annual revenue of US$115bn in 2017.

**Recent acquisitions, disposals and strategic partnerships**

**Potential strategic fit with ABR**
A strategic relationship with ABR could provide Koch Industries with a valuable source of borates used in its glass and fibreglass business.
**Intrepid Potash**

**Current business profile**
Intrepid Potash (IPI) is a fertilizer manufacturer based in Denver, Colorado. The company is the largest producer of potassium chloride (MOP), in the United States. It owns three mines; two in Utah and one in New Mexico. Intrepid has a current market cap. of US$455m.

**Earnings**
In the four quarters to September 2018, Intrepid achieved revenues of US$174m, and EBITDA of US$38m.

**Recent acquisitions, disposals and strategic partnerships**
Intrepid has been something of a turnaround story over the past year or so. Declining potash and fertilizer prices to near-decade lows over the last 6-7 years put the company into a difficult position. Over the past couple of years, management has countered this by cutting production costs, using a greater proportion of solar evaporation, expanding in salt, and by selling water to near-by oil and gas companies. Now the company is in a much stronger financial position. In fact, so much so, that Intrepid Potash’s 3Q18 presentation states that the “strong balance sheet allows Intrepid to explore additional high-margin and accretive opportunities inside and outside its fence”.

**Potential strategic fit with ABR**
Fort Cady could offer just such an opportunity. ABR could benefit from Intrepid’s strong balance sheet, and US distribution. Notably, ABR’s expected fully-up-and-running EBITDA of US$345m is substantial compared to Intrepid’s current earnings.

**Albemarle**

**Current business profile**
Albemarle Corporation is a global specialty chemicals company with leading positions in lithium, bromine and refining catalysts. The company is the largest producer of lithium globally and the second largest producer of bromine. Albemarle is headquartered in Charlotte, North Carolina. Its main producing assets are located in North America, and Chile. Albemarle has a current market cap. of US$8.9bn.

**Earnings**
In 2018, Albemarle achieved revenues of US$3.4bn, and adjusted EBITDA of US$1.0bn.

**Recent acquisitions, disposals and strategic partnerships**
Albemarle’s strategy (company presentation, February 2019) is to grow the lithium business, while maintaining the more mature bromine and catalysts businesses.

Albemarle’s recent M&A activity has been focused on expanding in lithium, and divesting non-core businesses. In 2015, Albemarle acquired Rockford Lithium, one of the world’s major lithium producers for US$5.7bn. In 2016, Albemarle acquired the lithium conversion capacity of Jiangxi Jiangli New Materials, for about US$145m. Jiangxi Jiangli is focused on the production of battery-grade lithium hydroxide and lithium carbonate. In 2018, Albemarle formed a 50:50 JV with Mineral
Resource Ltd of Australia for Mineral Resource’s Wodgina lithium project in Western Australia, which exports unrefined hard rock ore.

Albemarle has divested various noncore businesses over the past several years including the phosphorus business in 2012, its AOX (absorbable organic halides) business in 2014, and its polyolefin, catalysts and components business in 2018.

**Potential strategic fit with ABR**

Though Albemarle’s current strategy seems to be focused on expansion in lithium, there may be synergies between its existing businesses and boron. For example, Albemarle sells lithium bis(oxalate) borate (LiBOB), a chemical used in lithium-based batteries. In addition to batteries, lithium is also used in a diverse range of applications that use borates including glass and ceramics, lubricating greases and metallurgy. Bromine is used in flame retardants for electronics and construction materials, completion fluids for oilfields and in industrial water treatment.

**CF Industries**

**Current business profile**

CF Industries (CF) is the largest producer of ammonia and nitrogen globally, and a leader in nitrogen fertilizers. The company owns the largest nitrogen production base and distribution network in North America. The group is based in Chicago and has a current market capitalisation of US$9.0bn.

**Earnings**

In 2018, CF Industries achieved revenues of US$4.4bn and adjusted EBITDA of US$1.4bn.

**Recent acquisitions, disposals and strategic partnerships**

In 2010, CF Industries bought Terra Industries, positioning CF Industries as one of the largest players in nitrogen, and in the global fertiliser industry. CF Industries disposed of its phosphate mining and manufacturing business in 2014, selling the unit to Mosaic for US$1.4bn, in order to focus on its core nitrogen fertiliser business. In 2018, management was focused on returning excess cash to shareholders, repurchasing some US$500m worth of stock. About half of operating cash flow was returned to shareholders.

**Potential strategic fit with ABR**

CF Industries is focused on nitrogen.

**Yara International**

**Current business profile**

Yara International (YAR.OL) is a Norwegian company listed on the Oslo Stock Exchange. The company produces and sells nitrogen based fertilisers and related industrial products, as well as a range of phosphate and potash based fertilisers, and complex and speciality fertilisers. Yara is the second largest producer of ammonia, nitrates and NPKs globally. Yara has a worldwide presence with sales to 150 countries, but does not currently have any production assets in the US. The Norwegian government, through the Ministry of Trade, Industry and Fisheries, owns a 36.2% equity stake in Yara. The Norwegian Government Pension Fund owns a further 4.9%. Yara has a current
market capitalisation of US$898m.

**Earnings**

In 2018, the company achieved revenues of US$11.4bn and EBITDA, excluding special items, of US$1.5bn, up 7% YoY.

**Recent acquisitions, disposals and strategic partnerships**

In 2014, Yara was in talks with CF Industries as to a merger. One aspect of the deal, was the potential for Yara to gain access to cheaper gas (the main ingredient in ammonia) in the US market. The deal did not progress. Since then, Yara has made a number of acquisitions.

In 2017, Yara announced its investment in the Yara Dallol potash mine in Ethiopia. The project will employ solution mining and is expected to produce 600,000 tpa of SOP. Yara holds a 51.8% stake in Yara Dallol, with Liberty Metals and Mining Holdings (25%) and XLR Capital (23.2%) owning the rest. Yara has said that capital expenditure for the project will be lower the previously estimated US$740m.

Yara undertook a series of acquisitions and expansion projects in 2018, and has plans to ramp up other assets in 2019-2020. Capex was US$2.2bn in 2018, including US$0.7bn for M&A. Yara’s planned capex is US$1.3bn in 2019 and US$1.0bn in 2020, with no specific allowance for M&A activity (February 2019 presentation).

**Potential strategic fit with ABR**

Previously focused on nitrogen based fertilisers and related products, Yara is now entering the SOP market with its investment in Ethiopia.

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**Nutrien**

**Current business profile**

Nutrien (NTR) is the world’s largest provider of crop nutrients, selling more than 26m tpa of potash, nitrogen and phosphate products for agricultural, industrial and feed customers globally. It is the world’s largest producer of potash with ~12m tpa product sales, and the third largest producer of nitrogen with ~10m tpa nitrogen product sales. Nutrien operates six potash mines in Saskatchewan. In addition, Nutrien is the second-largest North American phosphate producer, selling ~3.5m tpa phosphate products. The group operates two large phosphate facilities in the US with integrated mining, and one large facility in Alberta, Canada. Nutrien has a current market cap of US$32.7bn.

**Earnings**


**Recent acquisitions, disposals and strategic partnerships**

The group was formed from the merger of Potash Corporation of Saskatchewan, and Agrium in January 2018. In July 2018, Nutrien bought Agrible, a digital ‘agtech’ start-up for US$63m. In October 2018, Nutrien sold Arab Potash Co, a transaction that was required by the Competition Commission of India and the Ministry of Commerce in China, in providing clearance for the merger. In December 2018, Nutrien sold its 23.77% stake in SQM to Tianqui Lithium of China.
In February 2019, Nutrien announced that it would acquire Australian business, Ruralco Holdings Ltd (RHL.AX) for A$469m. Ruralco is one of Australia’s leading agricultural services businesses. Ruralco provides a range of services to Australian farmers through its retail network, and provides agronomic advice and agency services. Ruralco is also a leading distributor of water products, provider of water infrastructure services, and broker of water entitlements to the Australian agricultural sector.

**Potential strategic fit with ABR**

Nutrien achieved some US$521m in annual synergistic benefits in 2018, and expects to achieve a further US$600m in savings in 2019. The current focus is on integrating the two businesses that merged. Nutrien produces sulphuric acid, a key input for ABR.

**Mosaic**

**Current business profile**

The Mosaic Company (MOS) is the world’s leading integrated producer and marketer of concentrated phosphate and potash. In October 2018, it announced that it is moving its headquarters from Plymouth, Minnesota to Tampa, Florida. Mosaic has some 10.4m tpa potash (MOP) capacity. According to the company’s website, Mosaic had potash market shares of ~13% globally, and ~42% in North America. Mosaic is also the largest producer globally of finished phosphates with annual capacity of around 16.8m tpa. Mosaic was formed in 2004 by a merger between Cargill’s crop nutrient business and IMC Global, a fertiliser company. Mosaic has a current market cap of US$10.8bn.

**Earnings**


**Recent acquisitions, disposals and strategic partnerships**

In 2014, Mosaic acquired CF Industries’ phosphate business, as well as Archer Daniels Midland’s fertiliser distribution business in Brazil and Paraguay. In 2018, Mosaic bought Vale Fertilizantes from Vale S.A.

**Potential strategic fit with ABR**

Mosaic seems focused on MOP and phosphate based fertilisers, and ramping up existing projects. Mosaic does produce sulphuric acid, which is a key input for ABR.

**Cargill**

**Current business profile**

Cargill Inc. is a privately held American group based in Minnetonka, Minnesota, and incorporated in Wilmington, Delaware. It is, arguably, one of the most established operating entities anywhere in the world. In terms of revenues, it is the largest private group in the US. Were Cargill a public company, it would have ranked 15th on the Fortune 500 list in 2015. The group is active in agriculture, animal nutrition, food and beverages, bio-industrial products, meat and poultry, pharmaceuticals, salt, transportation, and other services. Cargill is responsible for roughly one-quarter of all US grain exports. It supplies more than one-fifth of the US meat market. It is also the largest poultry producer
in Thailand.

Cargill offers North American farmers grain contracting and consulting solutions, crop inputs, and agronomic services aimed at increasing yields. The group offers crop protection, seed and fertiliser products and services across Canada.

In finance, Cargill offers risk management services in more than 100 commodities and currencies, varying from cattle feed to copper.

Earnings
Cargill reported revenues of US$114.7bn for the year ended May 2018, and adjusted operating earnings in the same period of US$3.2bn.

Recent acquisitions, disposals and strategic partnerships
Cargill is an acquisitive company. In 2015, the group acquired EWOS, which produces food for the salmon industry. In 2017, Cargill bought a stake in Memphis Meats, which produces beef and chicken from animal cells, and which eliminates the raising and slaughtering of cattle. In 2018, Cargill acquired Diamond V, a company focused on improving animal nutrition, and food safety. It also bought Polish company Konspol, which provides a range of products in the chilled convenience, frozen and cold cut categories. Konspol operates a feed mill, five broiler farms and two processing complexes in Poland.

In an interview with Bloomberg in September 2018, David MacLennan, Cargill’s CEO said that Cargill is looking to tap growing demand for alternative proteins.

Potential strategic fit with ABR
Cargill offers a wide range of services that could be utilised by ABR. It has strong distribution via its crop, seed and fertiliser services offered to North American farmers.
Borates: Robust outlook for demand

- Boron is a versatile and essential element used in a vast range of industrial materials, chemical processes and agriculture
- Demand is being driven by ‘big picture’ trends; urbanisation, energy efficiency, and food security
- Boron is at the bottom end of the ‘S-curve’; long-term, there is tremendous scope for demand expansion

Stable, non-substitutable, long-term demand growth

The global market for boric acid (H₃BO₃) reached 3.9m tonnes in 2017. The market has grown by almost 4% pa over the past few years. This robust growth looks set to continue driven by the ‘big picture’ trends of urbanisation, the move towards greater energy efficiency, and the need for increased food security.

Figure 23: Boric acid (H₃BO₃) demand (tonnes 000s)

Some sources refer to the market in terms of borates; the borates market was ~8.7m tonnes in 2017. This is trickier because different borates have different boron and boric oxide contents. Comparing the market on a boric acid or boric oxide basis ensures consistency. See Appendix 3 for a list of the main borates and their boric oxide (B₂O₃) content. In 2017, boric oxide demand was ~2.3m tonnes.

A critical, omnipresent element

Boron, and borates, are among the most widely used elements in society. Borates are used in the manufacture of borosilicate glass where they provide heat and chemical resistance, and scratch and shock resistance. Borates are a component in fibreglass, where they help the performance of the
glass threads, and by absorbing infrared radiation also the insulating performance. In ceramics, borates are used in frits that are used in glazes and enamels to improve lustre and durability. Borates are also used in the electrolyte of lithium ion batteries, and to coat battery anodes. In metallurgy, borates are used as fluxes and boron is used to harden steel that is used in the automotive sector, and in rare-earth magnets. Borates are essential in the control of pressurized water reactors in the nuclear industry where boron carbide is used in control rods and borates are used as corrosion inhibitors. In the oil and gas industry, borates are a component of high-viscosity well fluids, which helps in oil recovery. Borates are used as cleaning agents in both household and industrial products. In agriculture, boron is an essential micronutrient to plant growth, and is vital in photosynthesis.

Figure 24: Borates demand by end-use

Source: Visual Capitalist, Rio Tinto

‘Megatrend’ driven demand

Boron still in the early stages of consumption

In terms of the consumption of materials versus income per capita, boron can be thought of as a ‘late-stage’ mineral. Typically, as an economy starts developing, its consumption of minerals and metals starts to accelerate. Steel is a relatively early-stage metal that is used in basic infrastructure (in rebar and wire rod for example). Consumption of metals such as copper, that are used in building and construction, electricity, and transportation tend to take-off later in an economies’ development. Consumption of borates, used in agricultural products, energy efficiency and various applications associated with urban lifestyles, comes later still. According to data from Rio Tinto, world borate consumption is less than 10% of saturation level. Borates are at the bottom of the ‘S curve’, suggesting demand growth will remain strong over the next several decades.
Big picture trends
Given the diverse range of processes and industries in which boron and borates are used, it is no surprise that demand is driven by ‘big picture’ factors, rather than by any single segment of the economy. Demand for boron and borates is being driven by three global trends:

- **Urbanisation** – an increasing population, and an ever-greater proportion of us abandoning rural lifestyles, and living in cities

- **Energy efficiency** – a global focus. Boron is used in various applications including fibreglass insulations, lithium-ion batteries, and in magnets used in wind turbines

- **Food security** – a combination of population growth, the rising middle class, and declining availability of arable land is driving increased demand for fertilisers, and boron as an essential micronutrient

**Figure 26: Key drivers of boron and borates demand**

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<td>Automotive</td>
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</tr>
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</table>

**Source:** Orior Capital
Urbanisation

According to the United Nations World Population Prospects: The 2017 Revision, the world’s population is expected to grow from 7.6bn people in 2017 to 8.6bn in 2030, and to 9.8bn in 2050. That is, the world’s population is expected to grow by almost 80m people pa over the next decade and by an average of ~67m people per annum over the next three decades. The world population grew exponentially in the period 1900 to 2000, from 1.5bn to 6.1bn. Incredibly, this growth was three times greater than during the entire previous history of humanity. The global middle class is expected to grow more quickly. According to UN estimates, the global middle class will rise from 1.8bn people in 2009, to 3.8bn people in 2030, at an average growth rate of 3.6% pa, and to 5.4bn people by 2050.

The world is urbanising rapidly. According to the United Nations, the global urban population is expected to increase by almost 2.5bn people from 2014 to 2050, to more than 6.0bn. Much of this urbanisation is being driven by China and India, but other countries are urbanising rapidly as well. In terms of emerging economies, where materials consumption per capita is only just taking off, the next one billion urbanites are likely to come from Nigeria (population 190m), Indonesia (264m), Pakistan (197m), Bangladesh (165m), Philippines (105m), and Brazil (209m). In all, the UN expects Africa and Asia to account for 90% of the increase in urbanisation in 2014-2050.

Given the omnipresence of boron in modern life, urbanising populations consume more boron. In buildings, the main uses are in insulating materials (fibreglass), LCD televisions and electronics, appliances that use borosilicate glass, and in glazed ceramics.

**Figure 27: Expected increase in urban population, 2014-2050**

![Source: Morphocode, United Nations World Urbanization Prospects: The 2014 Revision, Highlights](image-url)
Urbanisation is not only being driven by large population centres. According to the UN, almost half the world’s urban population lives in cities with less than 500,000 inhabitants. In fact, the fastest growing urban populations are in Asian and African cities with populations of less than 1 million people.

**Energy efficiency**

Borates have many advantages in modern energy efficiency applications. For example, nowadays, wind blades used in wind farms are made from fibreglass. Fibreglass has low electrical conductivity (useful against lightning strikes), and low-density. In building and construction, fibreglass window frames have lower thermal conductivity compared to aluminium, superior strength-to-weight ratios compared to other materials, and are resistant to environmental impact. Boron is also used in lithium ion batteries in the electrolytes, and to coat battery anodes. Ferroboron is used in the production of rare-earth magnetics called neodymium magnets, or NdFeB magnets.

**Food security**

More people not only means increased demand for goods, it also means more mouths to feed. Population growth places demands on arable lands, as well as on water and energy systems, and increases the need for agricultural efficiency, and fertilisers. According to the UN Food and Agriculture Organisation (UN FAO), the amount of arable land per person is expected to decline from 0.22 Ha in 2018 to 0.18 Ha by 2050. This somewhat alarming trend means that land will need to be farmed more efficiently. This in turn is driving demand for fertilisers, and more specific plant nutrition products.

Boron plays a vital role in plant life, and by extension, all life. It is an essential micronutrient for the growth and health of all crops. In photosynthesis, the process by which plants convert sunlight into energy, boron helps raise the rate of transportation of sugars that are created in the leaves to the roots and fruits where they are needed. Boron also increases flower production, helps elongate pollen tubes, and promotes germination, as well as seed and fruit development. Boron and calcium are present in cell walls within plants. Boron also enables healthy transportation of water, nutrients, and organic compounds to the growing portions of plants.

Although boron is a naturally occurring element, boron deficiencies in plants are common. In fact, according to Mosaic, boron deficiency is the second most widespread micronutrient deficiency around the world, after zinc. It causes significant losses in crop production and crop quality. Boron deficiency affects vegetative and reproductive growth of plants, resulting in inhibition of cell expansion. In cases of severe boron deficiency plants can suffer from stunted development and the death of meristematic (cell dividing) plant tissues such as shoots, root tips, flowers, seeds or fruits, as well as reduced root elongation, failure of flowers to set seeds and fruit abortion. Low boron levels may also adversely affect pollination and seed set.

According to Mosaic, studies show that adequate boron nutrition improves root uptake of phosphorus (P) and potassium (K) by maintaining proper function and structure of root cell membranes. Also, experimental evidence suggests that adequate boron supply is needed for mitigation of aluminium toxicity in plants grown in low-pH soils.
Fibreglass and speciality glass

Boron is used in various types of glass. Together, these represent more than 40% of demand. Insulation fibreglass is the largest single use of borates. Borosilicate glass is another significant segment. Boron acts as a powerful flux. Fluxes, usually oxides, are used in the manufacture of glass, glazes and ceramics to lower the high melting point of the main components – usually alumina and silica. In insulating fibreglass and reinforcement fibreglass boron is used to reduce the melting temperature and viscosity, thus improving fiberizing efficiencies. Boron increases the strength of the fibres. In glassware, Boron provides a high degree of chemical resistance.

Insulating fibreglass

Insulating fibreglass is mainly used in commercial and residential buildings. It works by reducing airflow and thus heat transfer. This reduces energy usage and carbon dioxide emissions. Boric oxide in the glass fibres increases the absorption of infrared radiation, improving insulating performance. Fibreglass is also used in acoustic insulation.
There are different types of fibreglass. ‘E-glass’ is the most widely used, accounting for ~90% of global fibreglass consumption. It is a general-purpose fibreglass that is known for its strength and electrical resistivity. E-glass is a low alkali glass with a low sodium content. It can contain around 22% calcium oxide (CaO) and Magnesium oxide (MgO), and about 12% boric oxide.

**Borosilicate glass**

Borosilicate glass is made primarily from silica (usually over 80%) and boric oxide (B₂O₃) (typically 12–13%, though varying from 5% to as much as 30%). It has a low coefficient of thermal expansion (about one-third that of ordinary soda-lime glass) and it is less dense because of the low atomic mass of boron. Borosilicate glass is resistant to thermal shock, chemical attack, and can withstand scratches and impacts. As a result, it is widely used in applications that require good thermal resistance, chemical durability, or high light transmission. Applications include pharmaceuticals, solar energy systems, cookware, fluorescent tubes, lamp covers and laboratories. Borosilicate glass is also used in medicine where chemically neutral glass is required, and in vacuum flasks that need chemical resistance and durability. Other applications include runway reflector systems, automotive parts, optical communications products and optical glasses.
**TFT LCDs:** One of the fastest growing segments of demand for borosilicate glass recently is in flat panel displays such as liquid-crystal displays (LCDs). Typically, glass used in flat panel production contains 11-13% boron oxide. It is important that alkaline-free boric acid is used in flat panel glass because alkaline materials tend to degrade the thin-film transistor (TFT) properties, by getting mixed with the liquid crystal material. Sodium is an alkaline material. As a result, calcium based boron sources such as colemanite are used. **The increasing prevalence of flat glass in modern society underlines the need to develop new sources of colemanite, especially in the West.**

**Fibre-optics:** Boron is used in fibre-optic cables used in communications. Fibre-optic cables comprise an inner core with a high refractive index that is usually borosilicate glass, and an outer core with a low refractive index.

**Textile fibreglass**

Textile fibreglass is made up of continuous strand glass fibres. The fibres may be arranged randomly, woven into a fabric, or pressed into a sheet. The result is cheaper and more flexible than carbon fibre, and stronger than many metals by weight. It is used in a vast array of applications including in aircraft, boats, automotive, swimming pools, roofing, pipes, septic tanks and surfboards. The continued use of textile fibreglass in applications that traditionally have used steel or concrete bodes well for demand. Again, the most type of glass fibre is low sodium E-glass.

**Ceramics**

Ceramic glazes are the glass-like surfaces of tiles. They are used to increase the strength of the tiles, create a waterproof barrier, and for decoration. Borates are used as a glaze ingredient to form the glass-like structure, reduce viscosity to create a smooth surface, and reduce thermal expansion helping to ensure a good fit between the clay and the glaze.

Some ingredients of the glaze are water soluble, and cannot be applied directly to the clay surface. These ingredients are ‘fritted’ in an oven, a process which fuses them with elements such as silica and other added oxides, rendering them insoluble. The resulting frit is applied to the clay, before being glazed. The process of fritting also starts the glass forming process. This has the advantage of lowering the temperature at which the glaze has to be fired. These frit and glaze formulations can contain as much as 25% borates. According to Eti Maden, the entire market accounts for more than 13% of global borates demand.

Borates can also be added into the composition of tile bodies (as opposed to the glaze) where the borates act as both a flux and inorganic binder. This can make the tile stronger, helps the formation of the glass phase, and can reduce emissions in the furnace. In porcelain floor tiles, adding borates greatly increases the strength of the tile, meaning the tiles can be made thinner.

**Metallurgy**

Boron is used in a variety of metallurgical applications including in steel, refractory materials, welding fluxes, the manufacture of amorphous metals (non-crystalline metallic materials), rare earth magnets and coating materials. Usually, boron is used to reduce melting temperatures which saves energy, to increase strength (in steel), to reduce corrosion and to increase fluidity.
Steel

Boron is used as an alloying agent in high strength steels. Small amounts of boron, typically 5-30 ppm, dramatically increases the strength of the steel. This has uses in vehicle manufacturing where there is constant pressure to reduce mass and thus emissions, without sacrificing safety. The type of boron that is used in motor vehicles nowadays can have yield points as high as 1,350-1,400 N/mm² (196,000-203,000 psi). That is roughly four times stronger than typical high-strength steels. Boron steel has a variety of applications in vehicles including in safety bars around seats, door strengthening beams, centre pillars, and seat recliner brackets. Most global automotive makers were using boron steel in vehicles by about 2004. According to Volvo, the use of boron steel in the Volvo XC-90 safety cage rose from 7% in the original model to 40% in the 2014 model.

![Volvo XC-90 body structure](image)

Source: Volvo

In addition to steel, boron is used in solder and welding as a flux, in the manufacture of rare earth magnets, and in powder metallurgy, where the addition of boron can impart properties such as high conductivity and greater strength.

Lithium-ion batteries

Over the past few years, the global focus on reducing emissions, and the demand for greater energy storage capabilities have driven research into new battery technologies. The use of boron in batteries can help improve both graphite anodes, and electrolytes.

One substance, lithium bis (oxalate) borate [chemical formula LiB(C₂O₄)₂] is used in electrolytes of lithium-ion batteries. LiBOB is halide free and can replace traditional fluorinated compounds such as lithium hexafluorophosphate (LiPF₆), or lithium tetrafluoroborate (LiBF₄). This has the advantage of avoiding the formation of hydrogen fluoride (HF) which is highly corrosive.

In lithium-ion batteries, lithium ions move from the negative electrode (anode) to the positive electrode (cathode) during discharge, and back again when the battery is charged. Graphite anodes are susceptible to lithium deposition at high charge rates, which can cause safety issues. Borate coatings can alleviate this.
The graphite materials used to make electrodes for lithium-based batteries have to be heated at temperatures of ~3,000 °C, to form an orderly crystalline structure – a process known as graphitization. Adding borates, can lower the temperature needed for this process.

In addition, borates are used in electrical capacitors (devices that store energy) and in aluminium plate capacitors. The ‘supercapacitors’ used in electric vehicles used electrolytes that contain boron.

**Rare-earth magnets**

Neodymium magnets, also called NdFeB magnets, are the most widely used type of rare-earth magnet. They are permanent magnets made from an alloy of neodymium, iron and boron to form a Nd$_2$Fe$_{14}$B tetragonal crystalline structure. Boron makes up 1.0% to 1.2% by weight of the magnet. They were developed (independently) by General Motors and Sumitomo Special Metals in 1982. Neodymium magnets are the strongest permanent magnets available commercially. They have higher remanence (the magnetisation left behind in a ferromagnetic material after an external magnetic field is removed), and much higher coercivity (a measure of the ability of a ferromagnetic material to withstand an external magnetic field without becoming demagnetized).

Neodymium magnets have replaced other types of magnets in many applications such as motors in cordless tools, hard disk drives and magnetic fasteners. They are one of the commonly used magnets in motors for hybrid vehicles and EVs.

In hybrid and electric vehicles, neodymium (NdFeB) magnets are used in steering, transmission and braking systems (typically 160-200 grams per vehicle), door and window systems (67-85 g/vehicle), and entertainments systems (40-50 g/vehicle), according to electronicdesign.com. This use in hybrid and electric vehicles is expected to increase exponentially as the uptake of these vehicles takes off.

**Agriculture**

Boron is an essential micronutrient, and the second most commonly deficient nutrient. As a result, boron is an essential ingredient in some fertilisers. Typically, low concentrations of boron are found in soils that are acidic and sandy, in areas with high humidity and those with low concentrations of organic matter. Some plants are more susceptible to boron deficiency than others. According to US Borax, apples and broccoli fare worse than, say, bananas or barley. Cereals and grasses are generally less prone to boron deficiency than legumes and some vegetables. These differences could be related to cell-wall composition. Boron deficiency can cause incomplete pollination of corn, or prevent maximum pod set in soybeans.

Boron accounts for ~19% of the US micronutrient market share with an estimated value of ~US$160m in 2016 (Context Analysis). The market has grown strongly over the past few years. Context forecasts average annual growth in value at 9% pa in 2017 to 2022. Boron plays an important role in several plant functions, including cell wall formation and stability, pollination, and seed set. Although boron is an essential nutrient, like other minerals, tolerance of it varies by plant species. Some species such as sugarbeet, cotton and turnips are highly tolerant of boron, whereas some such as soybeans, peaches and grapes are sensitive to it. US consumption of boron as a micronutrient is ~16.7m tpa, with about 70% of this consumed in the North Central and Pacific states.
Boron deficiencies are common in areas with acidic sandy soils, which are common in the Pacific coastal region. This area is key for growing several fruits and vegetables that are often susceptible to boron deficiency. In the West North Central states (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota and South Dakota) there are regions with acidic soils where the pH is <6. This increases the likelihood of boron deficiencies. This area accounts for nearly 60% of the harvested area for sugar beets, and nearly 40% for alfalfa.

There are several products in the market aimed at countering boron deficiency. These products come from a variety of different boron sources of which boric acid and sodium borates in various forms are the two main sources. Sodium borates are highly soluble, and can be manufactured into dry or liquid products for soil or foliar applications. Boric acid is also highly soluble; it is the primary source of liquid fertilizers. Liquid fertilizers are typically about 10% boron.

One such product is Mosaic's Aspire. Aspire is a soil applied product that combines two forms of boron and potassium into one granule to ensure uniform nutrient distribution. Initially, Aspire only included sodium borate (for quick release), but the company added calcium borate to ensure season long availability of boron to crops. Aspire is a 0-0-58 (NPK) composition with 0.5% boron. Mosaic markets Aspire in more than 30 US states. According to Context, Aspire sells for a US$100/t premium over MOP fertilizer.

**A myriad of other industrial uses**

**Abrasive:** Boron carbide, produced by the reduction of boric acid with carbon at high temperature (typically 1,400 °C to 2,300 °C), is used as an abrasive in polishing, and as a loose abrasive in cutting, such as in water jet cutting.

**Adhesives:** Boron is used to control viscosity in starch based adhesives that are used in corrugated cardboard, and cardboard tubes.

**Detergents:** Boron acts as a bleaching agent. It helps control the alkalinity of soaps and synthetic detergents. Boron also lowers the heat and time required for washing, as well as protecting the machine against corrosion.

**Drilling fluids:** Borates such as colemanite and ulexite are used in various applications in the oil and gas industry including in drilling fluids where borate additives are used to control viscosity.

**Flame retardants:** Boric acid, and sodium borates are effective in reducing the flammability of cellulose materials. Both boric acid and sodium borates are water soluble, and can be absorbed by wood, acting as a preservative. Similarly, zinc borates are used in plastics.

**Fuel cells:** Boron compounds are used to produce sodium borohydride, which in turn are used as the source of hydrogen in new types of fuel cells.

**Nuclear reactions:** Boron-10, a naturally occurring isotope, is used in control rods of nuclear reactors, as a radiation shield and as a neutron detector. The controls rods are typically 2% boron.

**Personal care products:** Borate are used in anti-aging creams, baby creams, bath salts, cleansers, liquid soaps, moisturisers, petroleum jelly, sunscreen

**Refractories:** Ammonium pentaborate is used in compounds to extend the life of steel refractories

**Water treatment processes:** Borates are used to clean the semi-permeable membranes used in water treatment.
Borates: Supply duopoly, short of colemanite

- Supply is dominated by two companies, Eti Maden (Turkey) and Rio Tinto Borates (US), which together control ~80% of the market
- There are limited large-scale deposits; strikingly, Turkey is the only country with more than 30 years of resources
- New sources of supply are needed; Fort Cady offers a unique and essential calcium based resource

Current borates market is a duopoly

While the demand for borates and boron is diversified across an immense range of industries and applications, the supply side is very focused. Two main producers, the Turkish group Eti Maden, and Boron (US) which is part of the Rio Tinto group, supply about 80% of world borates demand. Rio Tinto supplied about 30% of world borates supply in 2017, with Eti Maden controlling about 50% of the world market.

Limited large-scale deposits

This is largely because there are relatively rare occurrences of economically viable borate deposits. Globally, there are four main areas recognised as having large-scale borate deposits. These are Anatolia (Turkey), California (USA), Central Andes (South America) and Tibet (Central Asia). In terms of different minerals, the deposits are even more scarce. For instance, borax (also called tincal) is mined in Turkey, the USA and Argentina. Colemanite, the main calcium-bearing borate, is currently only mined on a large-scale in Turkey with Eti Maden enjoying a virtual monopoly.

Figure 39: Major borate mines restricted to four main regions

Source: Borate deposits: an overview and future forecast with regard to mineral deposits, Cahit Helvaci, 2017
In fact, the world is not only overly-reliant on Turkey for a substantial portion of production, but also in terms of known resources. According to data from Cahit Helvaci, writing in the Journal of Boron (a Turkish science publication), Turkey has 224m tonnes of known economic boric oxide ($\text{B}_2\text{O}_3$) reserves, representing 62% of the world total of 363m tonnes. In terms of total reserves, whether deemed economic or not, Turkey has 563m tonnes, representing 64% of the global total of 885m tonnes.

**Fig 40: Known economic reserves, tonnes m, $\text{B}_2\text{O}_3$**

**Fig 41: Total known reserves, tonnes m, $\text{B}_2\text{O}_3$**

Sources: *Borate deposits: an overview and future forecast with regard to mineral deposits*, Cahit Helvaci, 2017, Orior Capital estimates

In terms of reserve life for economic deposits, Helvaci estimates that whereas Turkey’s economic reserves might last 155 years, no other country has a reserve life exceeding 30 years. This is an astonishing finding, and one that highlights the risk of single country dependency in the future.

**Fig 42: Estimated life of economic reserves (years)**

**Fig 43: Estimated life of total reserves (years)**

Sources: *Borate deposits: an overview and future forecast with regard to mineral deposits*, Cahit Helvaci, 2017, Orior Capital estimates
**Boron (US) production seems to have peaked**

One factor likely to exasperate this single country dependence is that production at Rio Tinto’s operations in California appear to have peaked. Rio Tinto produced 512,000 tonnes boric oxide in 2018. This was up just 6% from the production level in 2010.

**Figure 44: Boron (US) production, tonnes 000s**

![Boron (US) production, tonnes 000s](source: Rio Tinto annual reports)

**Few new sources of supply**

Furthermore, there are relatively few alternative sources of new supply expected to come on stream in the near future. Two projects are Rio Tinto’s Jadar project in Serbia, and Ioneer’s Rhyolite Ridge project in Nevada. Both of these projects are lithium-borate deposits that host minerals that are not currently processed industrially. As a result, both projects seem likely to require the development of new processing techniques. This is in direct contrast to the Fort Cady project where the processing route is based on feasibility study level work undertaken by previous owners of the project, well-established chemistry and standard processing equipment.

**Figure 45: Known active borates projects**

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<th>Rio Tinto</th>
<th>Ioneer</th>
<th>Erin Ventures</th>
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*Source: Company data*

Rio Tinto has spent 15 years examining the project since discovery. It has drilled 180,000m of core (Jadar Newsletter Q2/3, 2018), analysed more than 108 tonnes of rock chip samples, and spent more than US$100m (Jadar Fact Sheet, May 2018). Rio Tinto’s website states that Jadar is currently in the pre-feasibility stage and that “significant investment is necessary to continue the technical analysis and planning” which would be necessary to move from pre-feasibility to feasibility.
EU Critical raw material

It is this dependence on Turkey for supplies, and a lack of other new sources, that has prompted the EU, to classify borates as a critical raw material. The European Commission classifies critical raw materials by a series of measures including an import reliance, and a substitutability index. Currently the EU relies on imports for 100% of its borates demand, with 98% of imports coming from Turkey. The EU ranks substitutability on a scale of 0 to 1, with 1 being the least substitutable materials. The EU ranks borates 1.0 on this index.

Rio Tinto’s Jadar project, is located near to the town of Loznica, in Serbia. It was discovered in 2004, and named after the Jadar Valley. The deposit has been ranked as one of the largest lithium projects in the world, and also contains borates. Jadarite is a newly discovered mineral with chemical formula Na₂O₂Li₂O(SiO₂)₂(B₂O₃)₃H₂O. Jadarite was confirmed as a new mineral after scientists at the Natural History Museum in London and the National Research Council of Canada conducted tests on it. Jadarite differs from the fictional mineral kryptonite only in that kryptonite contains fluorine. At the time of the discovery, this created some excitement in the press.
Sulphate of potassium: Solid demand growth

- The US SOP market is seeing strong growth, especially in California which is ~35% of demand, and where a number of chloride sensitive crops are grown.
- Compass Minerals is the only SOP producer in the US; there is a good opportunity for ABR to enter the market, and potential for some type of tie-up with Compass.
- In addition to developing an SOP business, ABR may have opportunities to develop a high-value boron-rich SOP product.

Potash refers to any of the various mined and manufactured salts that contain potassium (K) in water-soluble form. It is an essential nutrient for food crops. Potash, together with nitrogen (N), and phosphorus (P), are the primary constituents of agricultural fertilisers. Fertilisers are sold with N-P-K labels that indicate the content of the product. A ‘5-10-15’ label for instance would indicate the product contains 5% nitrogen, 10% phosphorus, and 15% potassium in the form of potash. The optimal blend of these key nutrients depends upon various factors including the species of plant, and the soil conditions.

**SOP versus MOP**

MOP (potassium chloride, KCl) is the most commonly used potash fertilizer, representing about 90% of the total market. It contains about 46% chloride. MOP is appropriate for carbohydrate crops such as wheat, barley, oats and palm oil, and is suitable for plants that are resilient to chloride such as sugar beets, celery and others. The chlorine content means it is beneficial to soils that exhibit chlorine deficiencies. Sometimes the application of MOP has to be managed carefully, so as not to create chlorine toxicity, for example in susceptible leafy plants.

SOP (potassium sulphate) is a premium-value potash. It contains potassium, sulphur (about 18%), and almost no chlorine. The use of SOP can improve crop quality and yields, and make plants more resilient to disease, droughts and frost. It can also improve a plants ability to absorb other nutrients such as iron, and phosphorus. SOP can improve the yield, taste, colour and shelf life of crops. It is a higher-priced fertiliser that tends to be used on high-value crops such as fruits, vegetables, nuts, and coffee. SOP works well with high salinity soils. It is primarily used in the following categories:

- Chloride sensitive: potatoes, avocado, citrus, tobacco, berries
- High value: alfalfa, cotton, coffee, other fruits
- High sulphur demand: soybeans, sunflower, peanuts, canola

Potassium plays an important role in plants, especially in promoting enzyme activity. When activated, enzymes catalyse reactions that regulate multiple plant functions. Photosynthesis is controlled by an enzyme that requires sufficient potassium. Efficient stomata function, which can prevent microbial attack, also depends on the interaction of enzymes with potassium. (The stomata are the small pores on stems and leaves that open when water is available, and close when it is not). Sufficient potassium availability promotes healthy plant growth, and increased disease resistance. See USGS, Potash—A Vital Agricultural Nutrient Sourced from Geologic Deposits, 2016-2017.
SOP can be produced from both primary and secondary sources. Primary sources are salt lake brines which are found in China, the US, Chile and India. Secondary sources include chemical processing. About half of the global SOP supply comes from the Mannheim process, which involves reacting sulphuric acid together with potassium chloride in a furnace. Supply of SOP is being restrained by the fact that for every one tonne of SOP produced, there is 1.2 tonnes of hydrochloric acid by-product. Hydrochloric acid is difficult to dispose of. This is the process that ABR will use to generate hydrochloric acid, exactly because of this by-product generation; ABR needs the hydrochloric acid for the boric acid operation. Globally, the top five SOP producers account for ~75% of total production.

**Figure 46: Types of potash**

<table>
<thead>
<tr>
<th>Material</th>
<th>Formula</th>
<th>K₂O, %</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chloride (MOP)</td>
<td>KCl</td>
<td>60</td>
<td>Cl is a micro nutrient</td>
</tr>
<tr>
<td>Potassium-magnesium sulphate (Trio)</td>
<td>K₂SO₄ · 2MgSO₄</td>
<td>20</td>
<td>Mg and S are secondary nutrients. SOP based K, without Cl.</td>
</tr>
<tr>
<td>Potassium Nitrate</td>
<td>KNO₃</td>
<td>44</td>
<td>N and K based fertiliser. High priced.</td>
</tr>
<tr>
<td>Potassium Sulphate (SOP)</td>
<td>K₂SO₄</td>
<td>50</td>
<td>S is a secondary nutrient, marketed as K, without Cl.</td>
</tr>
<tr>
<td>Polyhalite</td>
<td>K₂Ca₂Mg(SO₄)₂ · 2H₂O</td>
<td>14</td>
<td>Ca, Mg and S are secondary nutrients</td>
</tr>
</tbody>
</table>

Source: ABR

**More people, more food, more fertilisers**

Global fertiliser demand was ~75m tonnes in 2017, of which MOP demand was ~68m tonnes, and SOP demand was ~7m tonnes. Demand has risen by an average of ~2% pa over the past 5 years. The key drivers of demand are seen as being population growth, changing diets, and the declining availability of arable land.

According to USGS, global potash deposits are concentrated with three countries Canada (46%), Russia (35%) and Belarus (8%) having nearly 90% of reserves. Some 12 countries are large-scale potash producers, but still two-thirds of supply comes from Canada, Russia and Belarus. Typically, developing countries have increasing crop yield requirements (resulting from historical under-use of potash), and thus potash demand in these countries is strong. Some countries in Asia and Latin America have almost no potash reserves at all, and are heavily reliant on imports. About 80% of potash supply comes from international trade.

This has also given rise to a new wave of potash exploration. According to USGS, over the past decade, potash exploration has occurred in more than 40 locations, and development has begun in at least 20.

As the global population, and especially the middle class in China and other emerging economies continues to expand, it is expected that increasing demand for specialty crops will drive consumption of SOP.
Opportunities in SOP

Robust demand
According to Crystal Peak (company presentation, 1Q19), US SOP demand was estimated at 440,000 tonnes in 2018. Demand is expected to grow at ~4.8% pa over the next few years, having grown at almost 5% pa since 2009. SOP is primarily consumed in states that grow high-value or chlorine sensitive crops. The top six states are California, Washington, Idaho, Florida, Utah and Kentucky. Together these states account for ~70% of US consumption.

California accounts for more than 35% of US SOP consumption. This is mainly because the state has significant areas – around 375,000 acres – of chloride sensitive specialty crops including citrus fruits, avocado, and berries. Washington accounts for about half of planted US pome fruit area, and is also a major producer (second after Idaho) of potatoes, which are sensitive to chlorine. Idaho is the primary potato growing state in the US, and also grows more than a million acres of high-value alfalfa. Utah has more than half a million acres of alfalfa.

Few suppliers
Compass Minerals is the only active SOP producer in the US. Compass uses solar evaporation in some 200 km² of manmade ponds to concentrate, evaporate and harvest potash from its Great Salt Lake operation.

One acre is one chain (66 feet) multiplied by one furlong (660 feet). It is equivalent to ~0.4 hectares (ha). Traditionally chains 66 feet long (with 100 links) were used in surveying. A furlong is 10 chains, and the distance oxen could plough before resting. An acre is the area that could be ploughed in one day. The word derives from the old English words furch (furrow) and lang (long).
Two companies are currently developing SOP operations in Utah. Crystal Peak Minerals Inc. (CPM.V) is a development-phase company focusing on a speciality fertilizer project in southwestern Utah.

The company currently controls ~124,000 acres in the Sevier Playa region of Utah, and plans to develop a mining site to produce SOP and other minerals via solar evaporation. Production is expected to begin in 2022, with estimated annual SOP production of ~298,000 tpa over the 30-year life of the project. The company published a feasibility study in January 2018 with a post-tax NPV₈ of US$730m an IRR of 21% and an initial capex requirement of US$398m.

SOPerior Fertilizer Corp (SOP.TO) (formerly Potash Ridge) is an exploration and development company focused on the exploration of alunite to produce SOP, sulphuric acid, and alumina at its Blawn Mountain Project in Utah. The project covers ~15,000 state-owned acres. The company released a technical report in 2017 suggesting average annual SOP production of ~210,000 tpa over a 46-year mine life.

There seems to be obvious opportunities for new entrants; especially in the local California market, the biggest user of SOP.

**Potential for an SOP-Boron product**

At present, most boron fertilizer is sold as standalone product rather than in mixes so as to provide enhanced grower flexibility in mix partners and application rates. In markets with high SOP demand, and with crops that require higher boron consumption, it may make sense to develop an SOP-Boron blended product. This applies mainly to the Pacific coast, especially in sugarbeets (California, Oregon, Idaho), potatoes (Idaho) and Alfalfa (Arizona, Idaho and Oregon).
Gypsum: Sulphur so good

- Gypsum is a relatively low value bulk commodity that is generally sold near to source and demand is primarily driven by the construction sector.
- Gypsum is expected to account for just 2% of ABR’s revenues.
- Growth opportunities exist in agriculture where Pacific soils benefit from calcium.

Fort Cady will generate gypsum as a by-product. This will be small at first, since gypsum production requires the boric acid plant to be up and running, but by the time that Phase 1 (1A and 1B combined) is completed, the project should generate ~62,200 tpa gypsum. By Phase 3, gypsum production will reach an anticipated 310,000 tpa. This is expected to account for just ~2% of project revenues (accounted for as boric acid by-product credits).

Global gypsum market growing quickly; US market more mature

Whilst gypsum is a low value commodity that is produced in 81 countries, and generally sold close to where it is produced, the growth prospects – especially in emerging markets – are good.

According to World Cement (April 2017), the global gypsum market amounted to 252m tonnes in 2015. Of this amount, 61% was used in cement manufacture and a further 33% in the production of gypsum board. World Cement expected growth in demand of around 10% pa, with the vast majority of this growth coming from Asia, the Middle East and southern and eastern Africa. This is being driven by increased in spending on infrastructure and housing.

According to USGS, US gypsum consumption was ~34,700 tonnes in 2017, having grown by an average of 6.6% over the past 4 years. In 2017, some 15.9m tonnes of gypsum were mined in the US, represented ~7% of world total. This supply was supplemented by an additional 14.6m tonnes of synthetic gypsum and imports, mostly from Mexico and Canada.

Figure 49: US gypsum consumption, tonnes 000s

Figure 50: US gypsum price, calcined, US$/t
Broadly, western and central US have access to natural gypsum supplies and that determines the bulk of consumption. Eastern US has a preponderance of coal-fired power plants and hence a greater supply of synthetic gypsum.

**Fig 51: US gypsum fertiliser consumption by region**

**Fig 52: US gypsum and coal production**

Gypsum can readily supply both calcium and sulphate and as a result has a number of applications in agriculture. Crops with high sulphur demand include alfalfa, soya beans, peanuts and canola. Crops with high calcium demand include peanuts, tomatoes, almonds and fruit and vegetables. Gypsum is also used to rehabilitate soils in the reclamation of sodic soils (high sodium), the treatment of aluminium toxicity, to improve soil structure and to reduce run-off and erosion.

### Gypsum to treat sulphur deficiency

Growing gypsum use is partly attributable to increased sulphur deficiency resulting from higher crop yields, and the need to rehabilitate soils. Gypsum use is the cheapest way to correct this. Although sulphur was once an abundant nutrient in soils, research suggests that sulphur deficiencies in crops have increased over the past decade. For example, according to USA Gypsum, over the past decade alfalfa grown on some silt loam and loam soils in Iowa have shown increasing sulphur deficiencies evidenced by stunted growth and poor colouration. Early corn growth has also exhibited sulphur deficiencies.

This has been driven by a number of changes over recent years including the move towards earlier planting in colder weather (which restricts microbial processes needed for sulphur to become available to plants), stricter emissions controls which have resulted in less sulphur being deposited through precipitation, and the use of ‘high analysis’ fertilisers. For example, according to the Pioneer (part of DuPont) Ordinary Super Phosphate (0-20-0) contains up to 10% sulphur, whereas the newer Concentrated/Triple Superphosphate (0-46-0) contains less than 3% sulphur.

US demand depends mainly on soil and crop properties. The Pacific Coast states of California, Oregon and Washington have areas of heavy, waterlogged, and aluminium-rich soils, that benefit from gypsum’s ability to improve soil structure. California grows 99% of US almonds as well as a significant amount of fruit and vegetables, all of which have high calcium needs. In the South Atlantic region, soils tend to have high potential for aluminium toxicity. About 70% of US peanuts are grown in this region, as well as tomatoes and watermelon, both of which have high calcium requirements.
**Figure 53: Sulphur deposition in the US**

![Sulphur deposition in the US](image)


**ABR could offer a high-boron gypsum product**

Assay results on product from ABR’s bulk sampling in 2018, demonstrate the ability to produce a gypsum product with elevated levels of calcium and sulphur, that is very rich in boron, and yet low in phosphorus, manganese and iron.

*Figure 54: Assay results highlight the ability to produce a boron-rich gypsum product*

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Units</th>
<th>Synthetic</th>
<th>Natural</th>
<th>ABR sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>%</td>
<td>12</td>
<td>19.1</td>
<td>24.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>%</td>
<td>0.03</td>
<td>1.35</td>
<td>0.02</td>
</tr>
<tr>
<td>Sulphur</td>
<td>%</td>
<td>18.7</td>
<td>15.1</td>
<td>19.55</td>
</tr>
<tr>
<td>Boron</td>
<td>ppm</td>
<td>26.7</td>
<td>9.4</td>
<td>1033</td>
</tr>
<tr>
<td>Iron</td>
<td>ppm</td>
<td>264</td>
<td>1045</td>
<td>106.81</td>
</tr>
<tr>
<td>Manganese</td>
<td>ppm</td>
<td>5.5</td>
<td>14.6</td>
<td>4.52</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>ppm</td>
<td>16.7</td>
<td>30.6</td>
<td>&lt;2.0</td>
</tr>
</tbody>
</table>

*Source: ABR*
Appendix 1: Fort Cady chemistry

The Fort Cady project will employ a number of basic chemical processes. There are three main reactions, each producing a different product. The products are boric acid, sulphate of potassium (SOP) and gypsum. The raw materials are potassium chloride and sulphuric acid, both of which must be purchased, as well as the in-situ colemanite.

Sulphate of potassium

Following the chronological plan of the DFS, the initial product (Phase 1A) will be mainly sulphate of potassium (36,287 tonnes) and boric acid (5,443 tonnes). The build out of the boric acid capacity to an eventual 408,233 tonnes will take place in subsequent phases. The basic SOP reaction is:

\[
2\text{KCl} + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{HCl}
\]

The advantage of this process is that it creates an in-house supply of hydrochloric acid that will be utilised in the extraction of boric acid. Onsite production eliminates the need to transport large quantities of hydrochloric acid. In addition, management has deep knowledge of the fertiliser market and sees opportunities to sell potassium sulphate into the US market. Also, there is ready availability of sulphuric acid in neighbouring Nevada, where there is demand from the gold industry.

Boric acid

ABR plans to mine colemanite (calcium based borate) to recover the contained boric acid. This requires that dilute hydrochloric acid be pumped into the ground (at about a 4% solution). This effectively separates the boric acid, and generates calcium chloride as a by-product. Essentially,

\[
2\text{CaO}.3\text{B}_2\text{O}_3.5\text{H}_2\text{O} + 4\text{HCl} + 2\text{H}_2\text{O} \rightarrow 6\text{H}_3\text{BO}_3 + 2\text{CaCl}_2
\]

Gypsum

The calcium chloride by-product from the boric acid circuit will be reacted together with sulphuric acid to create gypsum for the construction and agricultural fertiliser markets, and hydrochloric acid that will be fed back into the boric acid circuit. The reaction is:

\[
2\text{CaCl}_2 + 2\text{H}_2\text{SO}_4 + 4\text{H}_2\text{O} \rightarrow 2\text{CaSO}_4.2\text{H}_2\text{O} + 4\text{HCl}
\]

The colemanite resource contains other elements. For example, in addition to calcium chloride, strontium chloride could also be produced in small quantities and sold. In the US, strontium is used in pyrotechnics and signals (30%), ceramic ferrite magnets (30%), electrolytic production of zinc, and some other applications, including glass.
Terminology

Various companies and industry resources refer to boron, boric acid and borate. It is important to understand exactly what one is referring to.

**Boron:** Chemical element with symbol, B, and atomic number 5.

**Boric oxide:** The oxide of boron, chemical formula $\text{B}_2\text{O}_3$, also called boron trioxide and diboron trioxide.

**Boric acid:** Chemical formula $\text{H}_3\text{BO}_3$ (sometimes written $\text{B(OH)}_3$) and also known as hydrogen borate and boracic acid.

**Borate:** A term denoting a large number of compounds that are salts or esters of boric acid. For example, colemanite (hydrated calcium borate hydroxide) is a borate with chemical formula $2\text{CaO} \cdot 3\text{B}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$. Kernite (hydrated sodium borate hydroxide) is another common borate. It has the formula $\text{Na}_2\text{B}_4\text{O}_6(\text{OH})_2 \cdot 3\text{H}_2\text{O}$. See Appendix 3 for further discussion.

**Borax:** Hydrated sodium borate, formula $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, and a name associated with early washing powders.
Appendix 2: The Fort Cady project

Location

The Fort Cady project is located in the eastern part of the Mojave Desert region in San Bernardino County, California. The project is located about 200 km northeast of Los Angeles, close to the town of Newberry Springs, and is about 50 km east of the city of Barstow. The area is highly prospective for borate and lithium mineralisation. It is situated in the Hector evaporate basin, close to Elementis Speciality Plc’s Hectorite lithium clay mine. Geologically, the project has a similar setting as Rio Tinto Borate’s Boron operations located 120 km to the west-northwest, and Nirma Ltd’s Searles Lake operations located 140 km to the northwest.

Project history

The Fort Cady deposit was discovered in 1964 when Congdon and Carey Minerals Exploration Company found several colemanite zones at depths of 405m to 497m below the surface. In 1977, the Duval Corporation started land acquisition and exploration activities, and by March 1981, Duval had completed 33 exploration holes. Duval commenced limited scale solution mining in June 1981. The company completed 17 production wells over the following few years that were used for injection testing and pilot-scale operations. In all, Duval developed, tested and patented a unique, in-situ solution mining and solar evaporation process for converting colemanite into boric acid and...
calcium chloride while still underground.

In 1986, the project as acquired by Mountain States Mineral Enterprises (MSME). MSME conducted tests in which a dilute hydrochloric acid solution was injected through a well into the ore body and a boron-rich solution was withdrawn from the same well.

In July 1986, Fort Cady Minerals Corp was formed. Pilot plant operations were undertaken in 1987 and 1988, during which time some 450 tonnes of boric acid was produced. As a result, the project was deemed to be commercially viable, and efforts to get the project permitted for commercial scale operations began in earnest in 1990. The project received its final approval; for commercial scale operations in 1994.

Extensive feasibility study, detailed engineering and test work was carried out in the late-1990s and the early-2000s, including a second pilot plant that operated from 1996 to 2001, and which produced 1,800 tonnes of a synthetic colemanite marketed as “CadyCal 100”. This was produced using sulphuric acid, resulting in gypsum precipitation underground, and in the surface piping. At the time of the final test work, a combination of technical issues, low commodity prices and the controlling entity having other priorities meant the project was not commissioned.

In all, some US$60m has been spent on the Fort Cady project. This has included license acquisition, drilling and resources estimation, well-testing, metallurgical testing, feasibility studies, and pilot plants. Notably, the project has previously received all necessary operating and environmental permits for commercial scale solution mining operations.


**Land titles**

The operating permit awarded in 1994 covers some 6,500 acres. Fort Cady California Corp, a wholly owned subsidiary of ABR, holds around 4,409 acres, of which approximately 1,386 acres coincides with the approved project area.

There are several different types of land titles both within the project area, and adjacent to it. These include 240 acres of fee simple patented or privately held lands; 269 acres of surface areas owned with mineral rights held by the State of California; 2,380 acres of unpatented claims held by FCCC; and 1,520 acres of unpatented claims leased by FCCC from Elementis. Other areas within the project area are mainly unclaimed public lands managed by the U.S. Department of Interior, Bureau of Land Management (BLM).

There are some power lines traversing the project area. The land that these lines are on is held by Southern California Edison. The resources under these lands have been excluded from the DFS mine plan, though there may be scope to move the power lines in future which could extend the project mine life by about 5 years.
Permitting

The US has both Federal and State laws, as well as the oversight of the Environmental Protection Agency.

Solution mining on Federal Lands comes under the auspices of the Bureau of Land Management (under the Federal Land Policy Act). This act allows US citizens to locate mining claims on Federal Lands and to extract minerals under a Plan of Operations. The National Environmental Policy Act requires that all projects on public lands be reviewed, a process that is initiated with the submission of a Plan of Operations.

The Bureau of Land Management can either approve the project (the project has no environmental impact) or request either an Environmental Assessment (EA) (for limited impact) or an Environmental Impact Statement (EIS) (potential impact) prepared. The EIS is more onerous.


The Environmental Protection Agency (EPA) Underground Injection Control regulations identify five different classes of injection wells. Class III – Injection Wells for Solution Mining applies to Fort Cady. For Class III wells, the EPA has primacy over the State of California. The company is applying for a
Class III Area Permit, that will allow simultaneous operation of multiple wells. This is expected to be received by the end of this year.

In addition to the above, there are various regulations that pertain to solution mining in California. This includes the California Environmental Quality Act. This is similar to the National Environmental Policy Act, and is being conducted simultaneously with the Barstow Bureau of Land Management.

**Geology**

The project is located within the Hector Basin of the Barstow Trough, in the central Mojave. The Mojave is bounded by the San Andreas fault zone and the Transverse Ranges to the southwest, by the Garlock fault zone to the north, and Death Valley and Granite Mountains faults to the east. The region comprises a number of relatively low mountain ranges separated by intervening basins, with primarily alluvium floors.

The Barstow Trough is a structural depression characterised by Cenozoic (66 million years ago until the present time) sediments, including borate bearing lacustrine deposits, with abundant volcanism along the trough flanks. The northwest to southeast trending trough formed during Oligocene (33.9 million years ago to 23 million years ago) to Miocene (23 million years ago to 5.33 million years ago) times. As the basin filled with sediments, and surrounding highland areas were eroded, the basin expanded, and playa lakes, characterised by fine-grained clastic material and evaporitic chemical deposition formed in the lower, central areas of the basins.

The Lavic Lake volcanic field sits within this area, and hosts the project area. According to USGS, the Lavic Lake volcanic field contains four late Pleistocene cinder cones, three of which are in the Lavic Lake area, with a fourth located in the Rodman Mountains 20 km to the west. The Pleistocene period is the first epoch of the Quaternary period (the most recent geologic time period) that lasted from 2,588,000 to 11,700 years ago, spanning the world’s recent period of repeated glaciations.

The Pisgah Crater, a 100m high cinder cone, is the most prominent feature of the basaltic lava field, and located 3.2 km to the east, overlooks the project area. The project area is covered by recent basalt flows from Pisgah Crater.

The boron within the deposit is believed to have been sourced from thermal waters flowing into the basin from hot springs during times of active volcanism. Borates were precipitated as the thermal waters cooled, or as lake waters evaporated and became more saturated with boron.

There are three prominent geological features of note:

- The Pisgah Fault, which lies to the west of the ore body
- Pisgah Crater, 3.2 km to the east
- Fault B, an unnamed fault, located east of the orebody

The Pisgah Fault is a lateral fault in which the east side has been thrown up by at least 200m relative to the west side. Fault B, to the east of the orebody also exhibits at least 200m of vertical separation. The orebody lies between these faults, in an uplifted block.
Deposit geometry
The ore body is elongated, and trends north-westerly. It covers an area of ~2.46 km², at an average depth of 350m to 450m below surface. The concentration of boron-rich evaporates is roughly ellipsoidal along an axis trending N40°-W50°. The deposit dips at about 10° to the southeast. There is a zone hosting greater than 5% B₂O₃ mineralisation, that ranges in thickness from 20m to 80m and is 800m to 900m wide at its centre and about 3.4 km long.

The eastern margin of the deposit is roughly linear and parallel to the Pisgah fault that lies 1.6 km to the west. The northeast and northwest boundaries are controlled by facies changes to more clastic material with lower content of evaporites, and boron. The south-eastern end of the deposit is open-ended; further drilling is necessary to define the deposit limits.

Figure 58: Deposit geometry

Source: ABR, DFS December 2018

Solution mining
Solution mining is a process used to recover minerals through boreholes that are drilled into a deposit. A leaching solution (dilute hydrochloric acid in this case) is pumped into the deposit where it makes contact with, and dissolves, the ore. This dissolved ore is then pumped to the surface for processing. Solution mining (also called in-situ leaching or in-situ recovery, because the ore is dissolved in-situ) allows minerals to be extracted from an ore body without the need for conventional
underground or open-pit mining.

At Fort Cady, the idea is to pump dilute hydrochloric acid (the leaching solution) into the ore body and to dissolve 9.5% by weight boric acid ($\text{H}_3\text{BO}_3$). The acid reacts with the colemanite to produce boric acid and calcium chloride.

The Fort Cady ore body is suitable for in-situ solution mining. In particular:

- The ore body is deep, and below water tables
- It is confined vertically by impermeable layers
- Both the ore body and its confining later are structurally weak
- Faults in the area further confine the ore zone for in-situ leaching

The ore body lies about 400m underground, and ranges in thickness from 20m to 80m. For Phase 1 (1A and 1B combined), some 1.03m tonnes of ore will be dissolved (assuming a 70% extraction rate). For Phase 2, which is 245,000 tpa boric acid, some 3.1m tonnes of ore will need to be dissolved, and for Phase 3 (408,000 tonnes boric acid) 5.2m tonnes of ore will be dissolved.

$$1.03\text{m tonnes ore} \times 11.7\% \text{ boric acid grade in reserves} \times 70\% = 84,357 \text{ tonnes}$$

The DFS is based on a mine life of 21 years with total production over the period of 6.7m tonnes boric acid. This represents virtually all of the 6.9m tonnes of measured and indicated resources. Fort Cady also hosts substantial inferred resources amounting to 7.1m tonnes boric acid. This suggests there is excellent scope to form up additional reserves and to extend the mine life.

**Hydrochloric acid**

Hydrochloric acid will be used as the leaching solution giving boric acid, and calcium chloride that will be used a feedstock for gypsum production. Supplying heat to the injection solution improves the solubility of the ore body and thus the boric acid recovery rate. The DFS is based on a head grade recovery of 3.7% boric acid by weight. This seems conservative given that these grades were achieved during pilot plant operations by Mountain State Minerals in 1986 and without the use of heat. The injection solution will be left in-situ for 4-12 hours before the leachate is extracted.

The amount of hydrochloric acid in the injection solution is a key parameter for controlling the reaction. The aim is to maximise the reaction with the colemanite, whilst at the same time restricting any reaction with unwanted materials such as calcium sulphate. Sample solution can be withdrawn from the well and tested to determine whether the reaction has reached equilibrium. If the sample is too acidic, the solution can be left in the well for longer.

In the first 2-3 years of the project, the SOP plant will throw off more hydrochloric acid than the boric acid facility will be able to use. ABR will sell this excess hydrochloric acid into the US market. Hydrochloric acid is used in a variety of industrial and commercial applications. These include oil well acidizing where it is used in large quantities as a bore hole drilling agent, and in metal finishing, for instance, in the steel industry where it is used to remove iron oxide from basic steel prior to further processing. Hydrochloric acid is also used in food processing and in water treatment, and in the mining industry in ore processing – including in the solution mining of borates, of course.
Wellfield parameters
The well-field will cover about 1.1 km², sufficient to support in excess of 200 wells. Individual wells are able to support flow rates of 75 gpm (US gallons per minute; one US gallon is approx. 3.785 litres) during extraction of pregnant leach solution (PLS). The net flow rate is calculated as 25 gpm per well because only one-third of the wells will be in extraction mode at any one time. Usually, one-third of the wells will be in injection mode, one third in reaction mode, and one-third in extraction mode. Based on this, and assuming a head-grade of 3-5% boric acid, each well is expected to produce ~1,700 tonnes boric acid per annum. Each well is expected to have a life of around 8 years. During Phase 1 (1A and 1B combined) 52 wells will be in operation. This is expected to increase to 157 wells during Phase 2, and 262 wells by Phase 3.

\[
25 \text{ gpm} \times 3.785 \text{ (into litres)} \times 60 \text{ minutes per hour} \times 7,560 \text{ hours pa} \times 4\% = 1,716 \text{ tonnes}
\]

Figure 59: Typical well-head layouts

Source: In-situ.com, Well-Field Mechanics for In-Situ Mining

Wells will be spaced at 60m, average 457m in depth, and be drilled using standard rotary drilling technology. The surface distribution layout at the wellfield will have capacity of 1,309 gpm, and have separate injection and recovery operations. The basic well design that ABR plans to use has already proven to be successful at Fort Cady for both injection and recovery wells. The design uses 12.5-inch diameter holes, the wide diameter being necessary to accommodate 7-inch fibreglass casing.

Figure 60: Fort Cady site plan

Source: ABR, DFS December 2018
Hydrochloric acid is highly corrosive. Instead of using submersible pumps, the main means of recovery will by pumping compressed air into the recovery line in order to create up-flow of the PLS. This is called ‘airlift’. ABR successfully demonstrated this method of recovery in bulk sample testing in 2018.

Figure 61: Air lifting from a well

Source: ABR, DFS December 2018

Processing

ABR plans to produce at 99.9% pure boric acid. The process design is expected to comprise:

- Acid in-situ solution mining to produce a PLS concentrated in boric acid
- Clarification of the PLS
- Solvent extraction (SX) to purify the boric acid, and to increase its concentration
- Evaporative crystallisation of pure boric acid at 100°C
- Crystal dewatering and drying
- Regeneration of the crude boric acid mother liquor by sulfuric acid acidification to precipitate calcium and strontium while simultaneously producing hydrochloric acid
- Dewatering and storage of the gypsum by-product for resale
- Volume makeup of the regeneration liquor by adding process water, addition of concentrated makeup hydrochloric acid and liquor heating prior to reinjection
- Zero liquid discharge circuit for solid waste removal without tailings

ABR intends to use an injection solution heated to ~50°C, which is expected to be achieved primarily using the heat of reaction. The injection liquor will contain ~4% hydrochloric acid, together with 20% or greater calcium chloride (CaCl₂). This elevated calcium chloride level is a recent enhancement to the process that should improve the extraction of boric acid in the SX process. Raising the level of calcium chloride will be achieved by precipitating slightly less in the gypsum circuit.
Solvent extraction will enable the PLS to be upgraded from 3.7% boric acid to 8-10%, whilst rejecting impurities. Boric acid is readily and preferentially extracted in acid solutions by a long-chain alcohol such as 2-ethyl-hexanol or iso-octanol. The SX chemistry is:

**Extraction:** $\text{B(OH)}_3 + 3\text{C}_{18}\text{H}_{17}\text{OH} \rightarrow (\text{C}_{18}\text{H}_{17})_3\text{BO}_3 + 3\text{H}_2\text{O}$

**Stripping:** $(\text{C}_{18}\text{H}_{17})_3\text{BO}_3 + 3\text{H}_2\text{O} \rightarrow 3\text{C}_{18}\text{H}_{17}\text{OH} + \text{B(OH)}_3$

The DFS is based on work done at Hazen Research in 1992-1993. The assumptions are that 92% of the boric acid will be extracted and that stripping will be 90% effective.

The boric acid plant will be complemented by a Mannheim furnace operation to produce SOP. This is the most common method of SOP production. The process involves heating potassium chloride and sulphuric acid in a muffle furnace at above 600°C. Globally, this method accounts for 50-60% of SOP supply.

The equipment for the SOP process including the Mannheim furnace is primarily manufactured in China. ABR is currently evaluating various manufacturers for this equipment and have obtained quotes and proposals from manufacturers with experience in building plants from 10,000 ta to 100,000 tpa, globally.

**Figure 62: Plant diagram**

Source: ABR
Process recycling

Given the nature of the process the quantity of tailings is expected to be small. The residual material from the process can be split into three categories; a gypsum stream that will be sold; the zero-liquid discharge process that at full production will output some 2,700 tpa of tailings; and the SX process stream of crud, a large portion of which will be recycled. Non-recycled crud will be sent to an offset landfill.

Gypsum cake will be stored in a damned area on site pending sale. It is virtually insoluble in water and non-hazardous. The gypsum storage facility will stack the gypsum whilst also extracting drained fluids back into the process.

The zero-liquid discharge circuit is designed to extract solids from the tailings streams, whilst recycling fluids back into the process.

Infrastructure, services and logistics

Water
The project is expected to require some 100 gallons (1 US gallon is 3.785 litres) of process water. Water will be needed for solvent extraction, make-up for the processes, to supply the steam plant, wash the gypsum and for process cooling, fire safety, and sanitary uses. The proposed water wells will be located on the west side of the Pisgah Fault, where there are two existing wells, and four more proposed. The furthest proposed well is 12.9km from the process site. Each well will be equipped with a pump and pipe that joins a main water delivery pipe to the process site.

Power
It is expected that the project will use a cogeneration (combined heat and power) plant to generate 8.0 MW of power using steam from a natural gas fired boiler.

Road access
The project is accessed via I-40 and Route 66. The main access road, comprising gravel and base materials, will access the proposed plant site via the Pisgah Crater Road.

Gas pipeline
A gas pipeline will be constructed to connect the process plant with the existing Pacific Gas and Electric Company (PG&E) The pipeline will be about 1.8 km long, and run parallel to the Pisgah Crater Road to the project site. Natural gas will be supplied by Southern California Gas.

Labour
The project will employ 74 full-time employees. The production estimates in the DFS are based on the assumptions of 350 operating days per year at 90% availability, meaning 7,560 hours per year.
Appendix 3: Boron and borates

The fifth element

Boron, B, is the fifth element on the periodic table. It has two abundant and stable isotopes, B^{10}, and B^{11}; the only light element to do so. Boron is formed through a process called cosmic ray spallation.

Cosmic ray spallation is a naturally occurring nuclear reaction that causes nucleosynthesis. Cosmic rays are highly energetic charged particles from beyond Earth, including protons, alpha particles, and the nuclei of heavier elements. Cosmic rays cause spallation when a ray particle collides with matter (including other ray particles) resulting in the expulsion of protons and neutrons. As well as in deep space, this process occurs in the Earth’s upper atmosphere and crustal surface (the upper 10m). This process is believed to be responsible for the abundance in the universe of some light elements such as lithium, beryllium, and boron.

Boron is the only non-metallic metal that is electron deficient. Boron forms strong covalent bonds with oxygen. Boron-oxygen salts are called ‘borates’. The boron-oxygen bond can occur in either planar trigonal BO_3 units or as negatively charged tetrahedral BO_4 units. Most borates are salts containing a mixture of these boron-oxides. Borates are an unusually large group; more than 250 borates have been identified, though only a few are of any commercial importance. The most common are salts of sodium, calcium or magnesium.

Borates are widely distributed in nature, in mostly low concentrations. Typically, in soil and rocks borates occur with concentrations of up to 450 ppm boron. Boron is also present in seawater with a concentration of ~4.6 ppm. Boron is relatively rare in the Earth’s crust, making up only 10 ppm.

By 3.8 Ga, boron had been sufficiently concentrated to form its own minerals. According to Grew, these are believed to have stabilised ribose, which is an essential component of ribonucleic acid, and a precursor to life.

Borax, a sodium based borate, is the most common borate being mined, with significant supply coming from Turkey, the US, and Argentina. Kernite is also mined in the US. Mining of colemanite, the main calcium based borate, is currently restricted to Turkey. Datolite and szaibelyite production is confined to Russia and China.

Borates are formed in various different environments. The most important economic deposits are related to volcanic activity in orogenic belts. They occur close to converging plate margins, in arid climates, and non-marine evaporate environments, and are associated with andesitic-rhyolitic magmas. Commercial borate deposits in Turkey, the US and South America and other places are non-marine evaporates associated with volcanic activity.

Arid to semi-arid conditions are needed for the process of evaporation to deposit economic quantities of soluble borates. Hydrated borates may accumulate in a non-marine basin in several ways. They can be deposited as an apron around a borate spring, in which case ulexite, borax or inyoite are the primary minerals. They can form in pool that is fed by a borate spring in which case borax crystals tend to have formed in the bottom muds in or intermittently dried margins, as is the case at Clear Lake, California. If the spring flows are low or intermittent, then borates can accumulate just below the surface as is found in the playa deposits of California and Nevada. There
are also lake deposits, which required more than seasonal flooding, such as the borax and kernite deposits in California (US Boron), and Kirka (Tukey), that formed in a closed basin through the process of precipitation.

**Figure 63: Generalised playa lake depositional model**

Borates can be categorised into three groups:

- **Skarn minerals**, associated with intrusives, and comprising silicates and oxides
- **Magnesium oxides**, hosted by marine sediments
- **Sodium and calcium hydrates**, related to lacustrine sediments and volcanic activity. Fort Cady is in this category.

According to Helvaci, the following conditions are necessary for the formation of economically viable deposits in playa-lake environments:

- **Formation of the playa-lake environment**
- **Concentration of boron within the lake**
- **Sourced from andesitic to rhyolitic volcanics, ash falling directly into the lake, or hydrothermal flows**
- **Thermal springs close to the volcanic area**
- **Arid to semi-arid conditions**
- **Lake water with a pH of 8.5-12.0**
### Figure 64: Composition of main borates

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Empirical Formula</th>
<th>$B_2O_3$ Content, Wt %</th>
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<tbody>
<tr>
<td>Sassolite</td>
<td>$B(OH)_3$ or $B_2O_3 \cdot 3H_2O$</td>
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<tr>
<td>Borax (Tincal)</td>
<td>$Na_2B_4O_7 \cdot 10H_2O$</td>
<td>36.5</td>
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<tr>
<td>Tincalconite</td>
<td>$Na_2B_4O_7 \cdot 5H_2O$</td>
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<td>Kernite</td>
<td>$Na_2B_4O_7 \cdot 4H_2O$</td>
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<td>Ulexite</td>
<td>$NaCaB_2O_5 \cdot 8H_2O$</td>
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</tr>
<tr>
<td>Probertite</td>
<td>$NaCaB_2O_5 \cdot 5H_2O$</td>
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</tr>
<tr>
<td>Priceite (Pandermite)</td>
<td>$CaB_12O_{19} \cdot 7H_2O$</td>
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<tr>
<td>Inyoite</td>
<td>$Ca_2B_4O_{11} \cdot 13H_2O$</td>
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<td>Meyerhofferite</td>
<td>$Ca_2B_4O_{11} \cdot 7H_2O$</td>
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<tr>
<td>Colemanite</td>
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<td>Hydroboracite</td>
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<td>Inderborite</td>
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<td>Kurnakovite</td>
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<tr>
<td>Inderite</td>
<td>$Mg_2B_4O_{11} \cdot 15H_2O$</td>
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<td>Szaboelyite (Ascharite)</td>
<td>$MgB_2O_3 \cdot 3H_2O$</td>
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<td>Suainite</td>
<td>$Mg_3B_2O_5$</td>
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<td>Kotoite</td>
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<td>Pinoite</td>
<td>$MgB_2O_4 \cdot 3H_2O$</td>
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<td>Boracite (Strassfurite)</td>
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<td>Datolite</td>
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<td>Cahmite</td>
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<td>Danburite</td>
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<td>Howlite</td>
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<td>Vonsenite (Paigeite)</td>
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<tr>
<td>Ludwigite</td>
<td>$(Fe,Mg)_2Fe_2B_2O_7$</td>
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<tr>
<td>Tunnellite</td>
<td>Sr $B_2O_10 \cdot 4H_2O$</td>
<td>52.9</td>
</tr>
</tbody>
</table>

Source: Helvaci, Garrett

References:
- Boron and Borates, Robert B Kistler and Cahit Helvaci, 1994
- Borate deposits: an overview and future forecast with regard to mineral deposits, Cahit Helvaci, 2017
- Boron: From cosmic scarcity to 300 minerals, Elements, 13, 2017, E S Grew
Appendix 4: Salt Wells

In addition to the flagship Fort Cady Project, ABR has an earn-in agreement to acquire a 100% interest in the Salt Wells North and Salt Wells South Projects in Nevada, US, once the company has spent US$3m on the project. The projects cover an area of 36km² and are considered prospective for borates and lithium in the sediments and lithium in the brines within the project area. Surface salt samples from the Salt Wells North project area were assayed in April 2018 and showed elevated levels of both lithium and boron with several results of over 500ppm lithium and over 1% boron (over 5.2% boric acid equivalent).

The Salt Wells Borate and Lithium Projects are located in Churchill County, Nevada, USA. The Projects are within short proximity to major highways and within 25 km of the town of Fallon that has a population of over 8,500 people.

The projects lie in what is believed to be an internally drained, fault bounded basin that appears similar to Clayton Valley, Nevada, where lithium is currently produced by Albemarle Corporation, the only current production source of lithium in the USA.

The basin covers an area of around 110km². Borates were produced from surface salts in the 1800’s from the Salt Wells North site. With the exception of recent surface salt sampling from the Salt Wells North project, no modern exploration has been completed.

Figure 65: Location, Fort Cady and Salt Wells

Source: ABR
The author

Simon Francis is a UK qualified chartered accountant with significant experience in the natural resources and minerals sector. Simon led research in the sector in various roles at major financial institutions including Macquarie, Samsung and HSBC, in a career spanning more than 20 years. He has been involved in approximately US$4bn of capital raising, for a number of natural resources companies. Simon has been engaged in the financing of early stage companies using production agreements, and has privately funded exploration companies in various metals and jurisdictions. Simon seeks to deploy capital in undervalued mining and resources opportunities that have been missed by the market.