Experiments on Solution Mining of Borax at Boron, California

Donald S. Taylor
United States Borax & Chemical Corp.
Los Angeles, California

ABSTRACT

Experiments were conducted on recovering borax by solution mining from the ore body at Boron, California. Three cavities were produced, two of them interconnecting, and all were examined by conventional mining entry after removal of solution. Several hundred tons of borax were extracted and observations were made on behavior of the shale present, shape of cavity produced and effects of joining cavities. Efforts to control shape of cavity by change of liquid level were unsuccessful. Results achieved were useful in judging probable percentage recovery of mineral and in predicting costs for recovering refined borax from the solutions produced.

INTRODUCTION

The Kramer borate deposit near the town of Boron, California, was worked by underground methods for many years. As one part of a general consideration of alternate methods, it became desirable to learn something about recovery using solution mining methods. Extensive tests were carried out in 1948 and have not been publicly reported heretofore. As is well known, the deposit is now being worked by open pit methods and no use of solution mining is involved.

The ore body has been described in some detail (Barnard and Kistler, 1966). The tests carried out were in sections of ore body conveniently placed relative to the underground openings, so that well installation cost was reasonable and ultimate examination of openings was possible. Perhaps the most striking aspect of the work was the opportunity to enter and examine in detail the openings which were produced. Test locations were selected to be typical of richer strata in the ore body, except that they were confined to areas relatively devoid of kernite ($Na_2B_4O_7 \cdot 4H_2O$), so the soluble fraction was virtually entirely borax ($Na_2B_4O_7 \cdot OH_2O$). The insoluble matter present was largely shale.

METHODS USED AND RESULTS

Two locations in the ore body, both about 350 feet underground, were selected where a layer of competent shale above an ore section allowed placement and cementing of well casing. The mine layout allowed sampling of the same stratigraphic ore section in nearby locations, so the character of the ore being leached was quite well established. The ore character involved is indicated by the data in Figures 1 and 2.

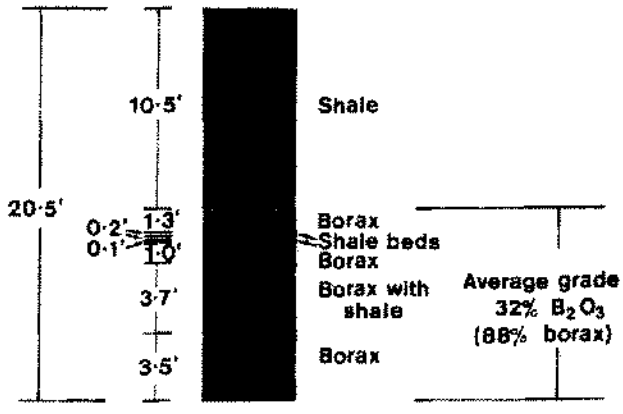


Figure 1. Log of test Well 2.

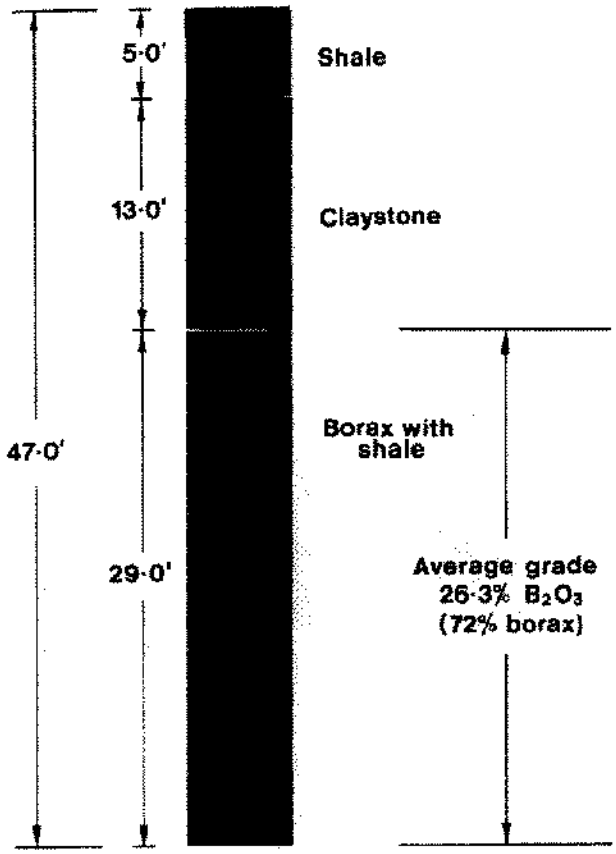


Figure 2. Generalized section in the vicinity of test Wells 3 and 4.

The arrangement of well fittings was quite simple, with the most complicated arrangement being shown in Figure 3. Straightforward arrangements were made for heating water electrically (due to location), pumping hot water, and for measurement, analysis, and disposal of solutions produced. Compressed air and movable exit pipes were used to control liquid levels in the cavity. Except for abortive (due to plugging) early attempts at downflow, all tests were made with injection of hot water at the bottom of the well. Water temperatures were near boiling or slightly superheated as allowed by pumping pressure.

Instruments were confined to simple temperature pressure measuring devices. A continuous calculation of ore volume removed could be made through measurement of volume and concentration of effluents. We had no means of determining hole shapes except after the fact, by lowering discharge outlets and measuring volume removed at different levels.

Well No. 2, the first successful well, was operated in high grade ore at Location No. 1. The dissolving section was 10 ft. deep, and after ten days of operation the effluent concentration began to decline. Typical operating conditions after five days are shown in Figure 4.

After ten days of operation the well was pumped out, and entry by mining showed the cavity to be as sketched in Figure 5. Virtually all the shale remained in the hole in a bed resembling sand and gravel, and accumulation of this material limited the shape to that of an inverted cone with steep sides.

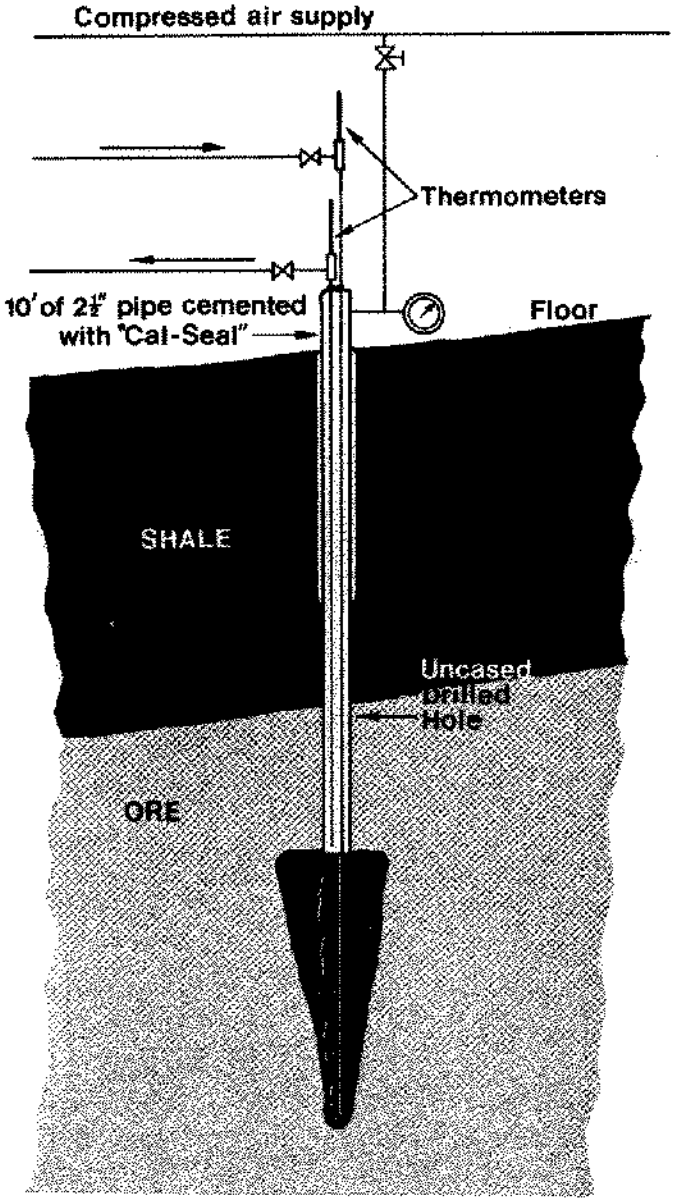


Figure 3. Well arrangement.

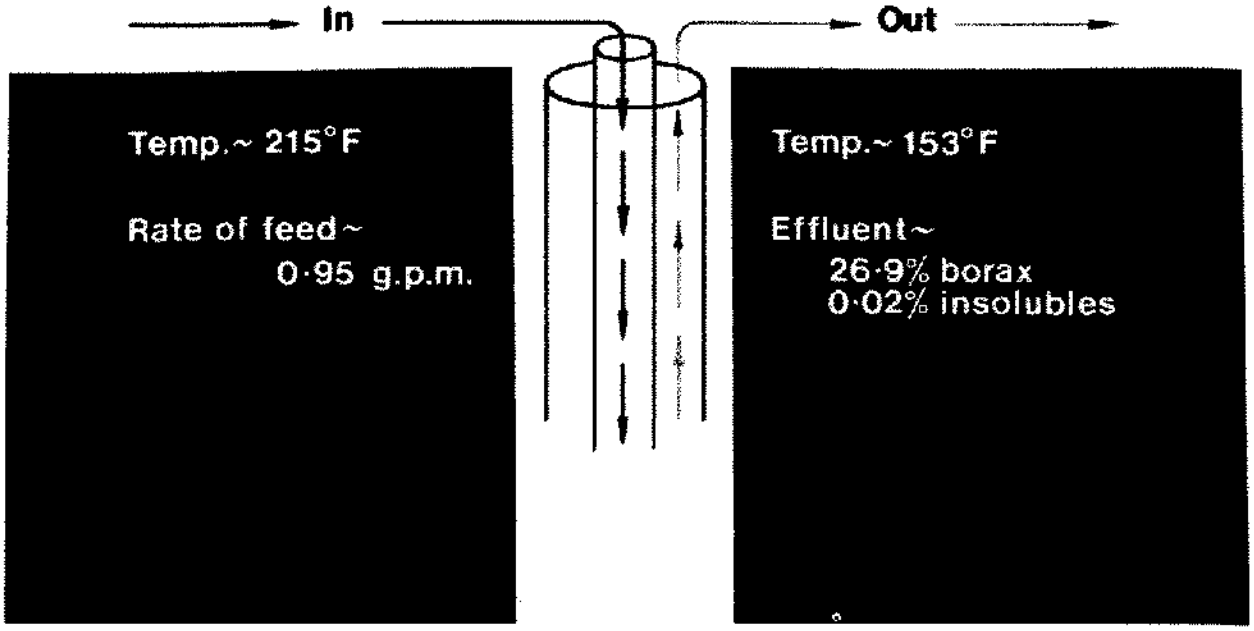


Figure 4. Typical conditions Well 2.

Well number 3 and 4 were operated in Location No. 2 in ore assaying 72% borax.

These wells were operated in succession and multiple levels in the cavity were used to try to control cavity shape. The total extraction of borax amounted to about 250 tons over a period of 38 days. Typical operating conditions were as shown in Figure 6.

The general character of results from Wells 3 and 4 can best be judged from Figures 7, 8, and 9, which are sketches of results obtained from probing and measurement after the cavities were entered.

Pictures taken after entering the cavity are interesting. Figures 10, 11, and 12 give an idea of appearance of the openings.

Note that the pictures show where solution levels were successively established to try to develop the cavity more regularly. General observations were:

1. Insoluble material did not slime but remained in the cavity in the "sand and gravel" type deposit controlling cavity bottom shape.

2. Efforts to make a cylindrical upper hole by raising the liquid level failed as dissolving continued at the widest diameter.

3. At the interconnection of the wells, large slabs of ore had fallen from the roof, apparently due to weakening along shale-rich layers. Due to particulate shale mixed with the slabs, dissolution of the slabs appeared to be permanently inhibited

DISCUSSION

It was concluded that the solution technique could not be sufficiently controlled to produce a high recovery under the conditions tested. It is evident that the numerous shale units have an important effect on cavity formation and limit cavity shape to less desirable forms. Though the tests were not of commercial scale, it was concluded that the same results would occur in larger wells operated in a similar manner. No attempt was made to evaluate more complex modes of operation such as fracturing.

REFERENCE

Barnard, R.M., and Kistler, R.B., 1965, Stratigraphic and Structural Evolution of the Kramer Sodium Borate Ore Body, Boron, California, *in* Second symposium on salt: Northern Ohio Geol. Soc., 1965, p. 133-148.

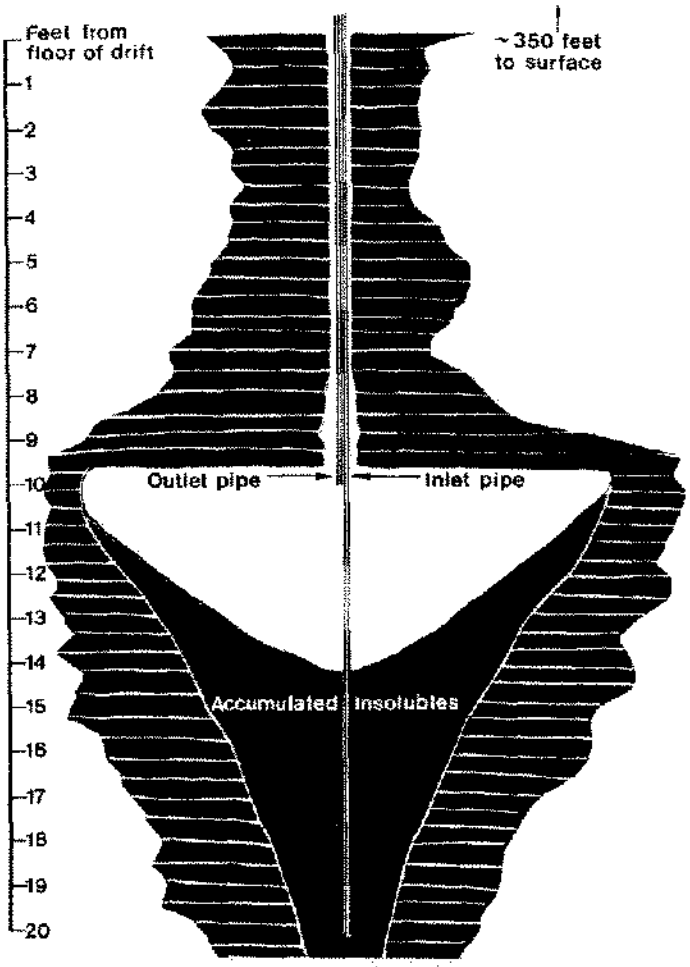


Figure 5. Vertical cross section of cavity from Well 2 (horizontal section roughly circular).

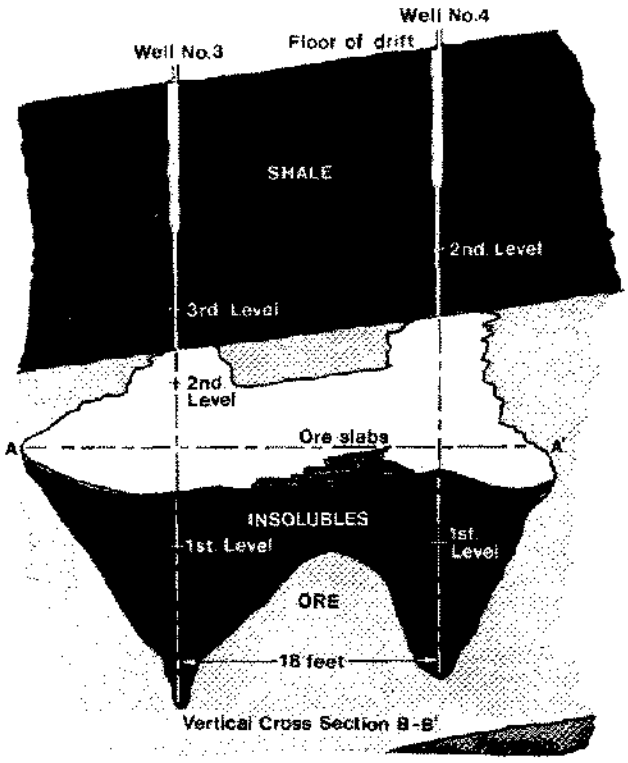


Figure 7. Vertical cross section Wells 3 and 4.

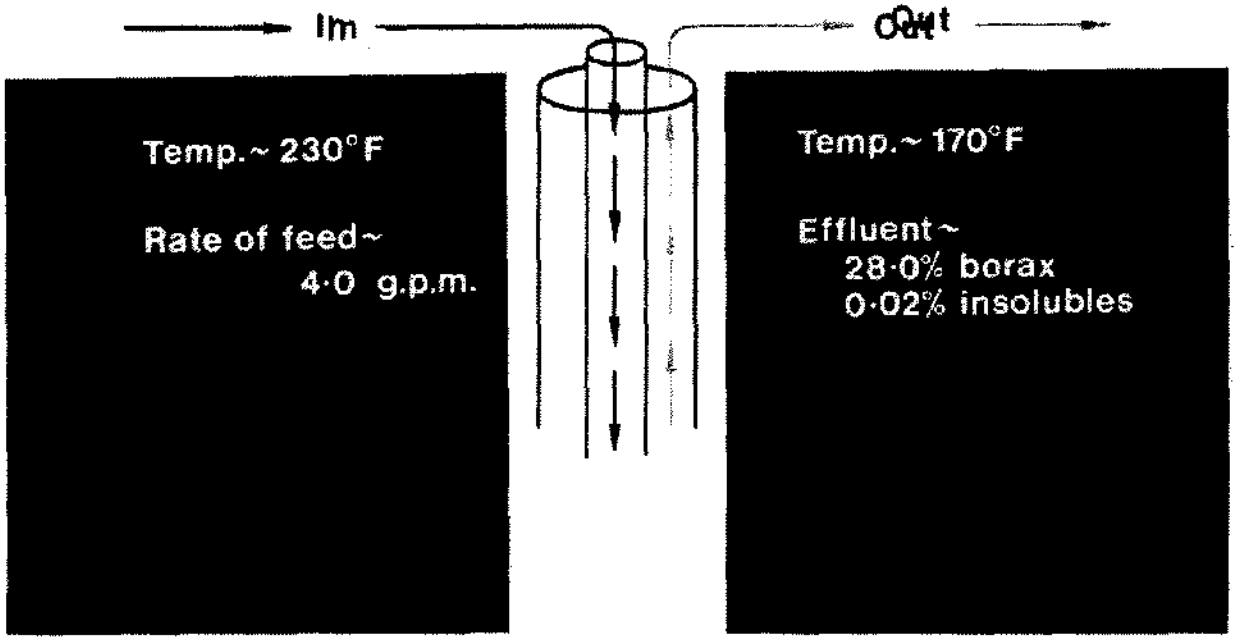


Figure 6. Typical conditions Wells 3 and 4.

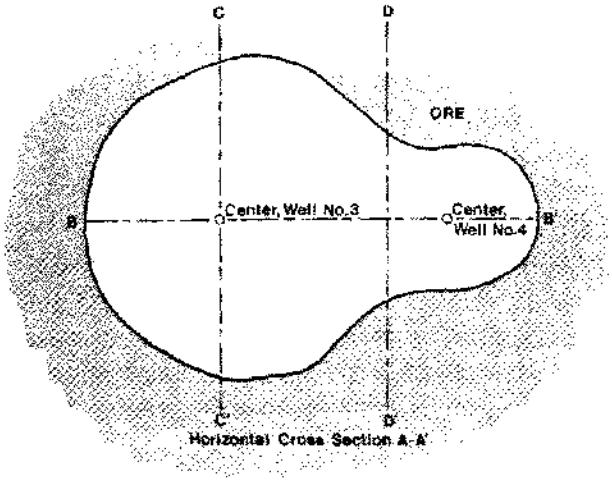
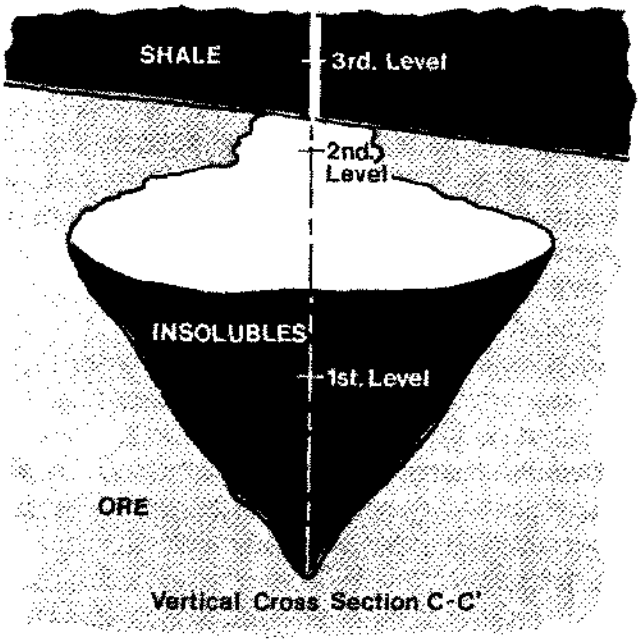


Figure 8. Horizontal cross section Wells 3 and 4.



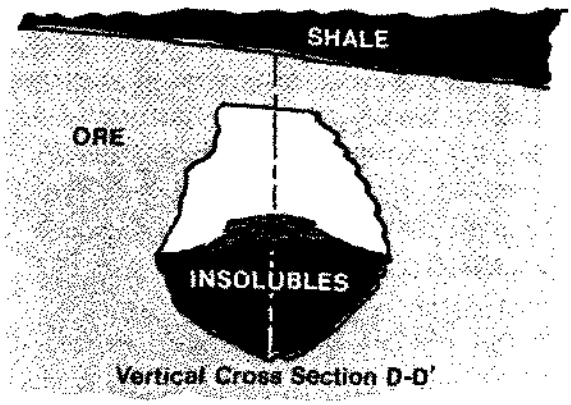


Figure 9. Vertical cross section at C-C' and D-D'.

Figure 10. Cavity from Well 8.

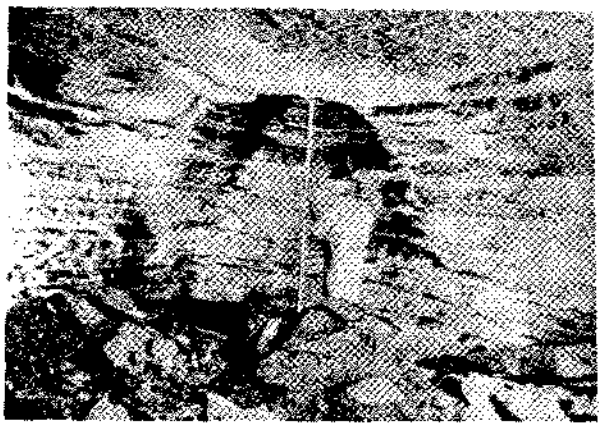


Figure 11. Cavity from Well No. 4.
Slabs on floor in center were from the operation. Slabs at sides w from barring down loose material.

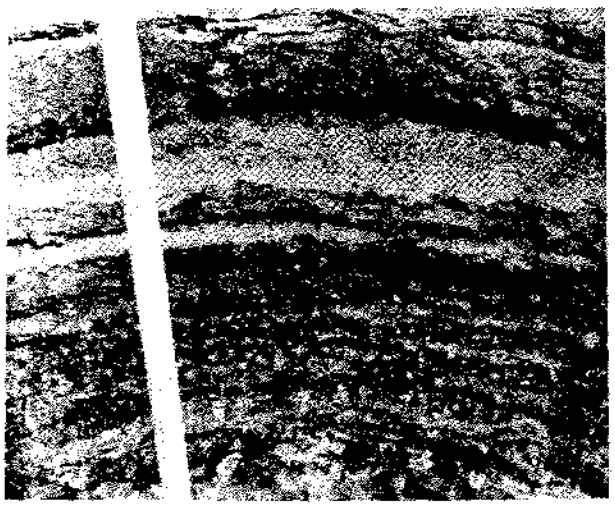


Figure 12. Wall from Well No. 4.
Close up of wall from well showing tendency for undercutting an ledge formation. Ledges are covered with loose, porous mass c shale matrix left by dissolving borax.