



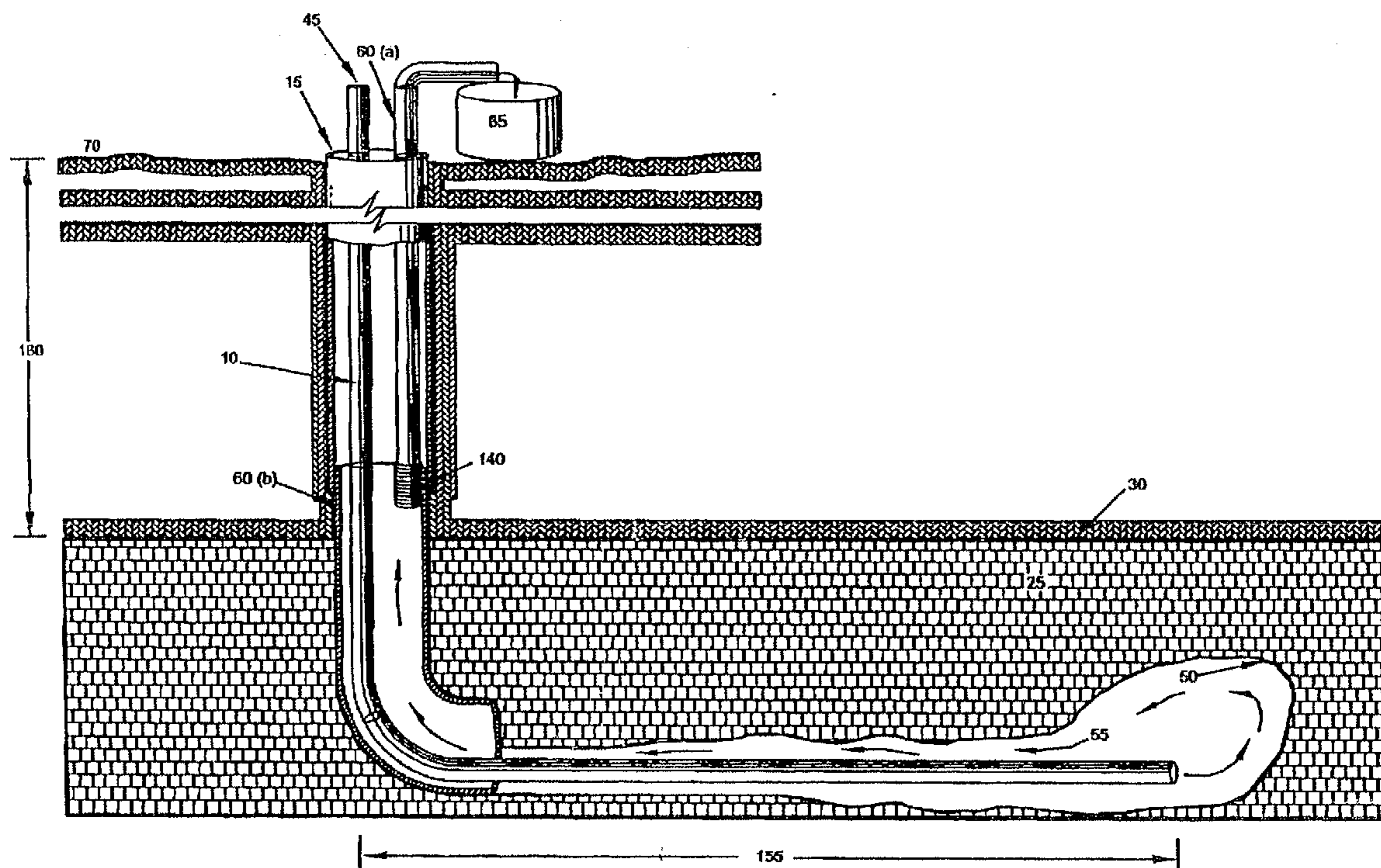
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(19) **United States**(12) **Patent Application Publication****Brown et al.**(10) **Pub. No.: US 2003/0029617 A1**(43) **Pub. Date: Feb. 13, 2003**(54) **APPARATUS, METHOD AND SYSTEM FOR SINGLE WELL SOLUTION-MINING**(52) **U.S. Cl. .... 166/305.1; 166/369; 299/17**(75) **Inventors: Neil Brown, The Woodlands, TX (US); Karl Nesselrode, The Woodlands, TX (US)**(57) **ABSTRACT**

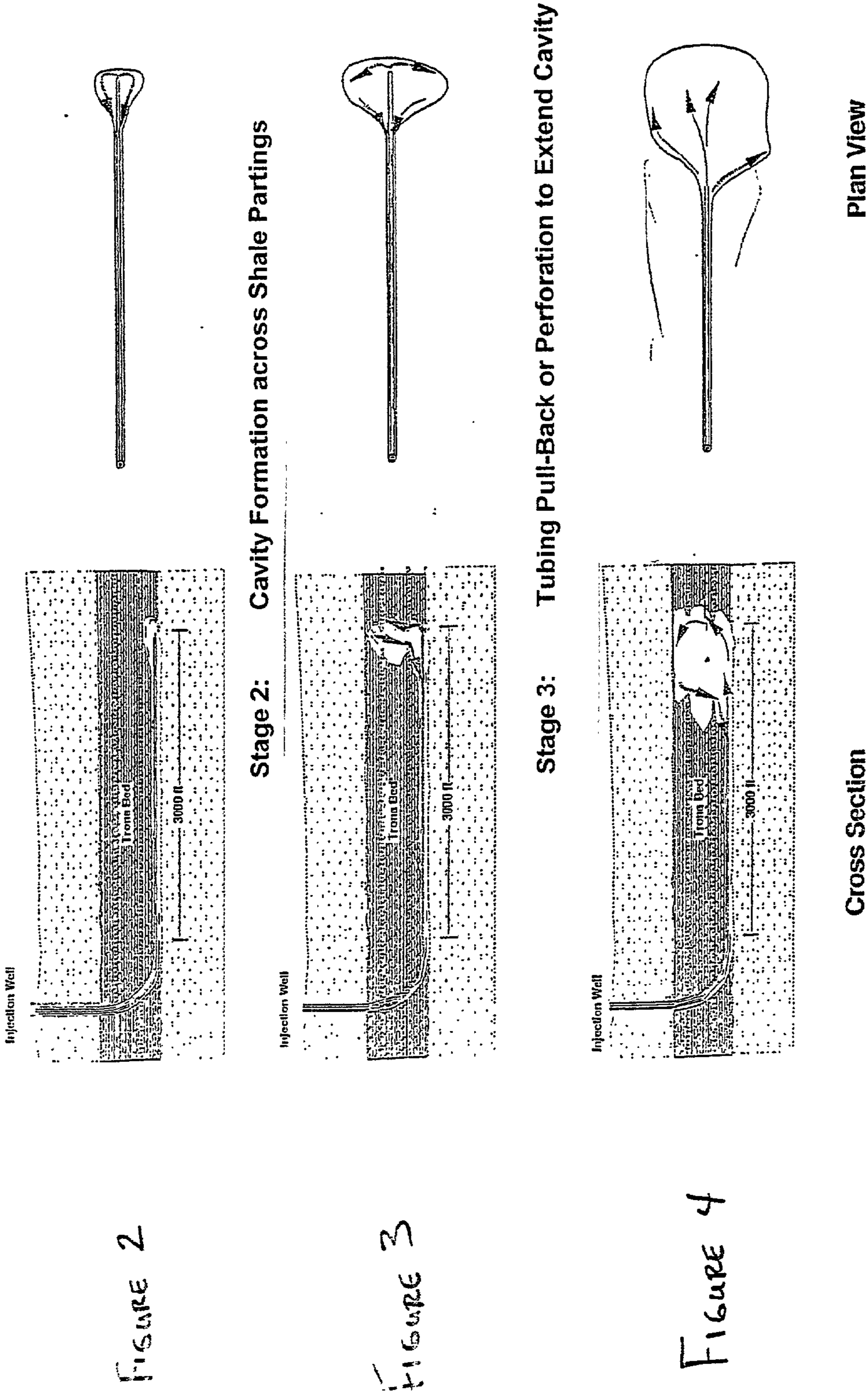
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The claimed invention is a method, system and apparatus for solution-mining of subterranean materials such as trona, nahcolite, thermonatrite, pirssonite, natron, dawsonite, wegscheiderite, gaylussite, shortite, halite, and other salts, minerals, and so forth. The method comprises injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material, and collecting the subterranean mixture from the elbow well. The system comprises a means for injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material, and a means for collecting the subterranean mixture from the elbow well. The apparatus further comprises a production casing, wherein the production casing has a production casing inner diameter of sufficient size to allow for production of a subterranean mixture of the fluid and the subterranean material between an outer surface of the injection tube and an inner surface of the production casing.







## APPARATUS, METHOD AND SYSTEM FOR SINGLE WELL SOLUTION-MINING

### BACKGROUND OF THE INVENTION

**[0001]** This invention relates to solution-mining of subterranean materials. The following discusses the disclosed solution-mining invention as applied to trona, but it is understood that this solution-mining invention applies to all subterranean materials.

**[0002]** The subterranean material trona, also known as natural soda ash, is a crystalline form of sodium carbonate and sodium bicarbonate, known as sodium sesquicarbonate, having the formula  $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$ . Worldwide, deposits of natural trona are rare, but the world's largest known deposit is located in the Green River Basin of southwestern Wyoming. Smaller deposits of trona are found near Memphis, Egypt and the Lower Nile Valley, widely throughout the soda lakes of Africa, Armenia, and Iran, and in the alkali deserts of Mongolia and Tibet. From natural trona, the primary end product is soda ash. In fact, Wyoming produces 90% of the processed soda ash in the United States and 30% of the world's supply. Other end-products from trona include sodium bicarbonate, caustic soda, sodium sulfite, sodium cyanide and sodium phosphate. Improved and cheaper processes for mining trona from natural deposits are desired.

**[0003]** Mining is an age-old approach for removing subterranean materials, e.g., trona, nahcolite, dawsonite, wegscheiderite, thermonatrite, pirssonite, natron, gaylussite, shortite, halite, and other salts, minerals, and so forth. Many deposits of subterranean materials, however, do not permit commercially viable extraction, whether through underground mechanical mining or solution-mining. For example, not even 10% of known trona deposits permit commercially viable underground mechanical mining, and trona solution-mining has not been economical.

**[0004]** Underground mechanical mining requires deep shafts to remove the subterranean material, and ever-deeper shafts are used as more material is extracted. In addition, mechanical mining is people-intensive. This creates a dangerous operating environment.

**[0005]** After lifting the material to the surface, the material is calcined to expel volatile components, such as carbon dioxide. Calcination is an energy-intensive processing step that affects the economics of mechanical mining. After calcination, the calcined material is recrystallized in aqueous solution, collected, dried and ready for further processing or shipping.

**[0006]** Solution-mining is a touted alternative to mechanical mining, but solution-mining has not proven as economical as desired. Solution-mining of subterranean materials, in particular, trona, is possible using hot water or alkaline solutions. For example, U.S. Pat. No. 2,388,009 (Pike) discloses the use of a hot water or hot carbonate solution as the mining fluid. See also U.S. Pat. Nos. 2,625,384 (Pike et al.); 2,847,202 (Pullen); 2,979,315 (Bays); 3,018,095 (Redlinger); 3,050,290 (Caldwell et al.); 3,086,760 (Bays); U.S. Pat. No. 3,184,287 (Gancy); 3,405,974 (Handley et al.); U.S. Pat. No. 3,952,073 (Kube); U.S. Pat. No. 4,283,372 (Frint et al.); 4,288,419 (Copenhafer et al.); and U.S. Pat. No. 4,344,650 (Pinsky et al.), all of which are incorporated

herein by reference. These disclosures, and other documented solution-mining processes, reveal use of two or more of the following economic drains on commercial viability: high temperatures, high pressure calcination, hydraulic fracturing ("fracturing"), and two wells, wherein one well is for injection and one well is for production, see e.g., U.S. Pat. No. 4,815,790, Rosar, et al.; U.S. Pat. No. 4,344,650, Pinsky, et al.; U.S. Pat. No. 4,252,781, Fujita, et al.; U.S. Pat. No. 4,022,868, Poncha, et al.; U.S. Pat. No. 4,021,526, Gancy et al.; and U.S. Pat. No. 4,021,525, Poncha, all of which are incorporated herein by reference. Fracturing rarely fractures only the material to be removed, so injecting hot water or alkaline solution dissolves other materials, including salts, and contaminates the subterranean material product collected from the production well. Collection of contaminated subterranean materials is yet another economic drain to commercial viable solution-mining processes.

**[0007]** In addition to solution-mining of trona, various U.S. patents disclose solution-mining of nahcolite (predominantly  $\text{NaHCO}_3$ ). For example, U.S. Pat. No. 3,779,602 (Beard et al.) and U.S. Pat. Nos. 3,792,902 (Towell et al.), and U.S. Pat. No. 3,952,073 (Cube) and U.S. Pat. No. 4,283,372 (Frint, et al.) disclose basic solution-mining of nahcolite and wegscheiderite (predominately  $\text{Na}_2\text{CO}_3 \cdot 3\text{NaHCO}_3$ ), all of which are incorporated herein by reference. Like the trona solution-mining processes, however, these nahcolite and wegscheiderite solution-recovery processes also possess economic drains on commercial viability.

**[0008]** A need, therefore, exists for improved solution-mining of subterranean materials through improved, more efficient methods and systems.

### SUMMARY OF THE INVENTION

**[0009]** The claimed invention is a method, system, and apparatus for solution-mining of subterranean materials. According to a first aspect of the invention, a method is provided for solution-mining of a subterranean material, the method comprising injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material, and collecting the subterranean mixture from the elbow well. According to another aspect of the invention, a system is provided for solution-mining of a subterranean material, the system comprising a means for injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material, and a means for collecting the subterranean mixture from the elbow well. According to still another aspect of the invention, an apparatus is provided for solution-mining of a subterranean material, the apparatus comprising an injection tube, wherein the injection tube has an injection tube inner diameter of sufficient size to allow for injection of a fluid for mining of a subterranean material. The apparatus further comprises a production casing, wherein the production casing has a production casing inner diameter of sufficient size to allow for production of a subterranean mixture of the fluid and the subterranean material between an outer surface of the injection tube and an inner surface of the production casing.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** FIG. 1 is a schematic of the cased elbow well drilled into a bed of a subterranean material, wherein the

elbow well comprises an injection tube, a production casing, and a production tube that is connected to a pump to help lift the subterranean mixture in the cavity to a collection location, here, the earth's surface.

[0011] FIG. 2 is a cross-sectional view of the initial cavity in the elbow well.

[0012] FIG. 3 is a cross-sectional view of the cavity in the elbow well, wherein the cavity is larger than in FIG. 2.

[0013] FIG. 4 is a cross-sectional view of the cavity in the elbow well, wherein the cavity is larger than in FIG. 3.

#### DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0014] The disclosed solution-mining invention is a device, method, and system for solution-mining of subterranean materials, such as trona, nahcolite, dawsonite, wegscheiderite, thermonatrite, pirssonite, natron, gaylussite, shortite, halite, and other salts, minerals, and so forth. Although this detailed disclosure focuses on the subterranean material trona, it is understood that the disclosed device, method, and system for solution-mining applies to all solution-minable subterranean materials.

[0015] In one example embodiment of the claimed invention, seen in FIG. 1, an elbow well 15 is drilled into a bed 30 of the subterranean material 25 being mined. An elbow well 15 is a well that begins at the earth's surface 70, and first penetrates vertically before penetrating horizontally. Although the elbow well 15 does not necessarily resemble the shape of a human elbow, there is a vertical portion that eventually turns to a horizontal portion. For trona, the estimated depth 160 for mining is 2000 feet below the earth's surface 70. Both an injection tube 45 and a production tube 60a are located in the elbow well 15, wherein 3-1/2" J55 tubing is used in one example for the injection tube 45, but other sizes and types of tubing will occur to those of skill in the art without departing from the scope of the present invention. A fluid 10 is injected into the injection tube 45, wherein the fluid 10 reacts with the subterranean material 25 to create a mixture 55 (e.g., a solution) and a cavity 50. The mixture 55 flows between the injection tube 45 and the production casing 60b. In another example embodiment, a pump 140 is attached to the production tube 60a to help lift the mixture 55 to the collection point 65 (here, the earth's surface 70).

[0016] Fracturing is unnecessary in many embodiments of the invention, because the injection tube 45, production casing 60b, and production tube 60a are in the same well 15. The elbow well 15, in some embodiments, is over 3000 linear feet in length 155 within the bed 30 of the subterranean material 25.

[0017] According to another embodiment of the invention, seen in FIGS. 2-4, the cavity 50 expands as more fluid 10 is injected into the well 15 dissolving more subterranean material 25. The cavity 50 expands outward from the end of the elbow well 15, and therefore the cavity 50 propagates back to the well 15. In the event that a collapse of the cavity 50, or other obstruction, reduces the flow of the mixture 55, the injection tube 45 is perforated in some embodiments to permit further amounts of the mixture 55 to be collected. Alternatively, rather than perforation, the injection tube 45 is

withdrawn, partially, until debris from the collapse is clear and flow of the mixture 55 is raised to an acceptable level.

[0018] High pressures of operation may cause the material 25 in the mixture 55 to escape before collection of the subterranean material mixture 55. Low pressures of operation, however, reduce the total collection of the subterranean material 25, because the cavity 50 may collapse prematurely. Selection of the well pressure to avoid these problems should be observed. At present, there is no known empirical method to make such selection other than trial and error. It is believed, however, that the following pressures and flow rates are acceptable, at least for trona: at 2000 feet deep, the pressure is 800-900 psi in the cavity 50 and the flow rate is 200-300 gal/min.

[0019] In further example embodiments of the invention, the subterranean material 25 is selected from a group consisting essentially of trona, dawsonite, wegscheiderite, nahcolite, thermonatrite, pirssonite, natron, gaylussite, shortite, halite, and other salts, minerals, and so forth.

[0020] In various example embodiments, the fluid 10 is selected from a group consisting essentially of water, a caustic mixture, a sodium carbonate solution, or any other fluid 10 capable of mechanically and/or chemically reacting with the subterranean material 25 to be mined so as to produce a mixture 55 capable of being removed from the production casing 60b through a production tube 60a. Such fluids 10 will occur to those of skill in the art. In some embodiments, the fluid 10 is heated.

[0021] In a further example embodiment, the mixture 55 is lifted, for example, by pumping with a pump 140 connected to the production tube 60a, and the mixture 55 is delivered to a collection location 65, such as the earth's surface 70. According to one example embodiment, an acceptable pump 140 comprises an electric submersible centrifugal pump, 140 such as those manufactured by Baker Hughes Centrilift. In addition, placement of the pump 140 is above the bed 30 of subterranean mineral 25, that is, above the mining areas. For example, with trona, the pump 140 is placed in some embodiments about 1100 feet below the earth's surface 70 in the elbow well 15. Other pumps 140 acceptable for use with the claimed invention include piston/cylinder pumps, driven by sucker rods from the surface 70. Still other pumps 140 acceptable for use with the claimed invention will occur to those of skill in the art.

[0022] Having thus described exemplary embodiments of the invention, it will be apparent that various alterations, modifications and improvements will readily occur to those skilled in the art. Such alterations, modifications and improvements, though not expressly described above, are nevertheless within the spirit and scope of the invention. Accordingly, the foregoing discussion is intended to be illustrative only, and not limiting; the invention is limited and defined by the following claims and equivalents thereto.

What is claimed is:

1. A method for solution-mining of a subterranean material, the method comprising:

injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material; and

collecting the subterranean mixture from the elbow well.

2. The method of claim 1, wherein the subterranean material comprises trona.

3. The method of claim 1, further comprising making the elbow well.

4. The method of claim 3, wherein making the elbow well comprises drilling an elbow well into a bed comprising the subterranean material.

5. The method of claim 1, wherein the method comprises casing the elbow well.

6. The method of claim 1, wherein said injecting the fluid further comprises injecting the fluid into an injection tube located in the elbow well.

7. The method of claim 1, wherein the method further comprises creating a cavity, wherein the cavity comprises the subterranean material.

8. The method of claim 7, wherein the cavity comprises the subterranean material mixture after said injecting the fluid.

9. The method of claim 1, wherein the subterranean mixture comprises a subterranean solution.

10. The method of claim 1, wherein the fluid comprises water.

11. The method of claim 1, wherein the fluid comprises a caustic mixture.

12. The method of claim 1, wherein the method further comprises heating the fluid.

13. The method of claim 1, wherein said collecting the subterranean mixture further comprises collecting the subterranean mixture through a production tube located in the elbow well.

14. The method of claim 1, wherein said collecting the subterranean mixture comprises pumping the subterranean mixture.

15. The method of claim 14, wherein said pumping the subterranean mixture comprises lifting the subterranean mixture through the production tube.

16. The method of claim 15, wherein the method further comprises delivering the subterranean mixture to a collection location.

17. The method of claim 16, wherein the collection location comprises the earth's surface.

18. The method of claim 14, wherein the method further comprises placing a pump in the elbow well.

19. The method of claim 1, wherein the method occurs at ambient well pressure.

20. The method of claim 1, wherein the method further comprises processing the subterranean mixture after said collecting the subterranean mixture.

21. A system for solution-mining of a subterranean material, the system comprising:

means for injecting a fluid into an elbow well, the fluid forming a subterranean mixture with the subterranean material; and

means for collecting the subterranean mixture from the elbow well.

22. The system of claim 21, wherein the subterranean material comprises trona.

23. The system of claim 21, further comprising means for making the elbow well.

24. The system of claim 23, wherein said means for making the elbow well comprises means for drilling the elbow well into a bed comprising the subterranean material.

25. The system of claim 21, wherein the system comprises means for casing the elbow well.

26. The system of claim 21, wherein said means for injecting the fluid further comprises an injection tube located in the elbow well.

27. The system of claim 21, wherein the subterranean mixture comprises a subterranean solution.

28. The system of claim 21, wherein the fluid comprises water.

29. The system of claim 21, wherein the fluid comprises a caustic mixture.

30. The system of claim 21, wherein the system further comprises means for heating the fluid.

31. The system of claim 21, wherein said means for collecting the subterranean mixture comprises means for pumping the subterranean mixture.

32. The system of claim 31, wherein the system further comprises means for placing a pump in the elbow well.

33. The system of claim 31, wherein the system further comprises means for delivering the subterranean mixture to a collection location.

34. The system of claim 33, wherein the collection location comprises the earth's surface.

35. The system of claim 21, wherein the system occurs at ambient well pressure.

36. The system of claim 21, wherein the system further comprises means for processing the subterranean mixture after said means for collecting the subterranean mixture.

37. An apparatus for solution-mining of a subterranean material, the apparatus comprising:

an injection tube, wherein the injection tube has an injection tube inner diameter of sufficient size to allow for injection of a fluid for mining of a subterranean material; and

a production casing, wherein the production casing has a production casing inner diameter of sufficient size to allow for production of a subterranean mixture of the fluid and the subterranean material between an outer surface of the injection tube and an inner surface of the production casing.

38. The apparatus of claim 37, further comprising a production tube for collecting the subterranean mixture.

39. The apparatus of claim 38, further comprising a pump connected to the production tube.

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