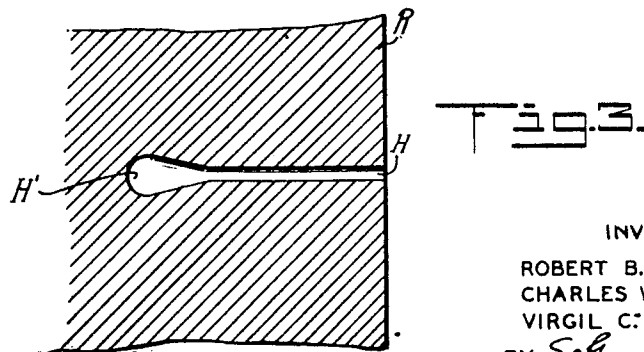
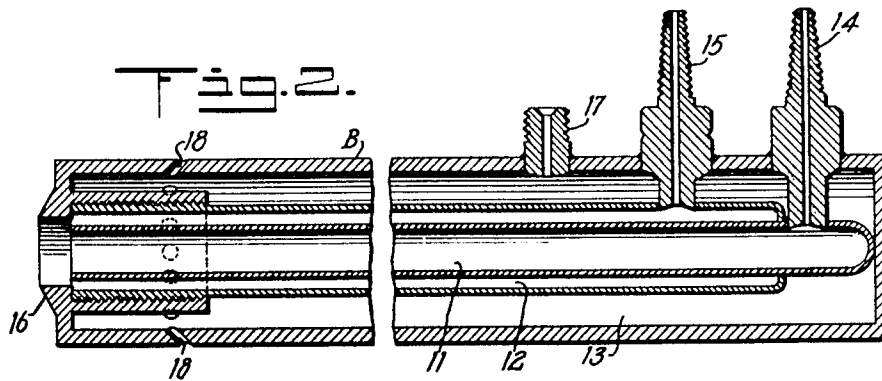
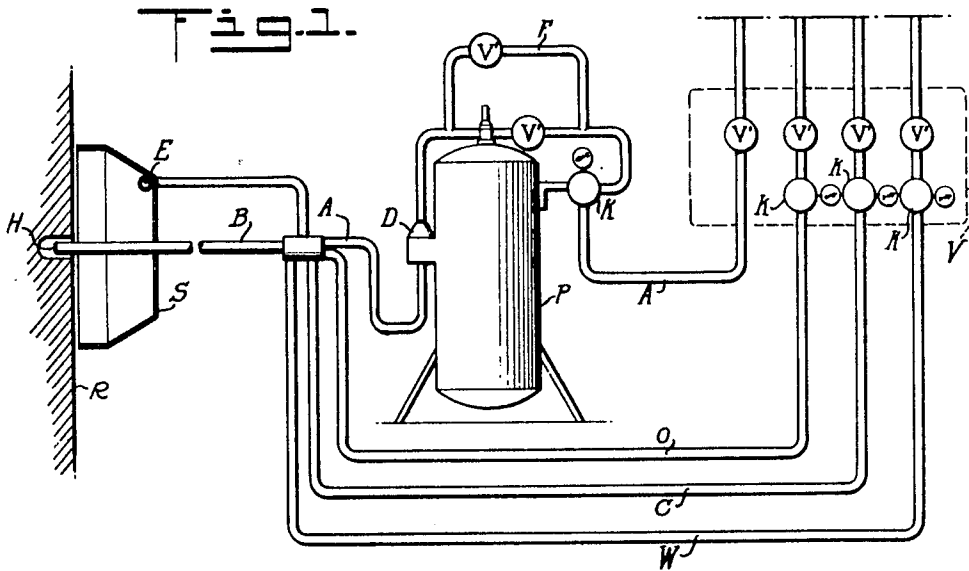


Aug. 24, 1943.

R. B. AITCHISON ET AL  
MINERAL CUTTING AND PIERCING

2,327,482

Filed April 18, 1939



INVENTORS  
ROBERT B. AITCHISON  
CHARLES W. SWARTOUT  
VIRGIL C. WILLIAMS  
BY *Ed. Greenwood*  
ATTORNEY

# UNITED STATES PATENT OFFICE

2,327,482

## MINERAL CUTTING AND PIERCING

Robert B. Aitchison, Grasmere, Staten Island,  
Charles W. Swartout and Virgil C. Williams,  
Kenmore, N. Y., assignors to The Linde Air  
Products Company, a corporation of Ohio

Application April 18, 1939, Serial No. 268,634

7 Claims. (Cl. 255—1.8)

This invention is a process for piercing, severing, grooving or otherwise working hard compact minerals and mineral-like substances, for instance the various forms of quartz, such as quartzite, jasper, and chert, other rocks such as dolomite, and mineral-like substances such as Portland cement concretes.

Piercing or cutting of such materials, as carried out in quarrying, mining, and similar operations, usually is accomplished by mechanical means, such as drilling, sawing, and chiselling, often aided by explosives such as dynamite. Such mechanical operations are slow and expensive and, in the case of pneumatic drilling of dynamite holes in particular, require the use of heavy, costly machinery and an investment in a large number of drill bits which must be resharpened frequently.

The very weight and bulk of drilling machinery precludes its use in inaccessible locations where it could otherwise be used to good advantage. For example, in the customary methods of quarrying and mining certain rocks, quartzite for instance, the first or primary dynamite blast produces a large proportion of blocks which require further reduction by secondary blasting. The large blocks are for the most part inaccessible to mechanical drilling apparatus, so practically all secondary blasting must be carried out by the expensive process of "sand blasting," which involves placing an explosive charge on the top of a boulder, covering the charge with sand or debris, and depending on the downward force of the explosion to shatter the boulder. Sand blasting does not use explosives efficiently.

Mechanical piercing or drilling operations also generally produce large quantities of fine dust particles which may constitute a serious industrial hazard to the health of workers, particularly in underground mines where dust may be closely confined to the scene of operation. In such operations, therefore, it is necessary to provide expensive equipment to exhaust the dust to protect the workers' health.

An object of this invention is to provide a novel thermal process for economically and rapidly piercing, severing, grooving or otherwise working materials of the kind described.

Other objects of the invention are the provision of such a process which shall be particularly applicable to the piercing of holes for blasting or other purposes; which shall permit the use of novel portable and relatively light and

inexpensive equipment; and which shall be clean and dustless in operation.

The manner and means of attaining these and other objects of the invention will become apparent from the following description, taken in connection with the accompanying drawing, in which:

Fig. 1 is a schematic diagram illustrating an arrangement of apparatus suitable for carrying out the process of the invention;

Fig. 2 is a longitudinal sectional view of one type of piercing blowpipe suitable for carrying out the process of the invention; and

Fig. 3 is a longitudinal section through a typical blast hole which has been produced by the process of this invention and is ready for the reception of an explosive charge.

Many minerals and mineral-like substances have the property of mechanically disintegrating by the breaking away of small fragments from the parent body when intense heat is applied to localized areas thereof. This type of thermal disintegration is commonly termed "spalling" and will be so termed throughout this specification and in the claims. The property of spalling under the application of heat is characteristic of substances having a high coefficient of thermal expansion and a low thermal conductivity, of substances which evolve relatively large quantities of gases or vapors when heated, and of substances which undergo a phase change, e. g. in crystalline form, when heated. Examples of substances which may be readily spalled by the localized application of intense heat thereto are quartz, quartzite, jasper, chert, and dolomite; and the general class of substances possessing this property will be termed hereinafter "heat-spallable" substances.

In one modification, the process of the invention involves the controlled directional spalling of such substances solely under the action of localized intense heat for piercing or otherwise cutting masses thereof. It is of particular value in quarrying or mining operations where large numbers of blasting holes must be pierced to receive charges of explosives.

The invention will be specifically described in connection with its application to blast-hole piercing in heat-spallable rock, using a high temperature oxy-fuel gas flame as the source of heat. Although other sources of high temperature heat may be used with some degree of success, we prefer to use a large and intense oxy-acetylene flame.

As illustrated diagrammatically in Fig. 1, an

apparatus for rock piercing includes a heating instrumentality in the form of an elongated oxy-acetylene blowpipe B to which are supplied acetylene, oxygen, compressed air, and water through the supply conduits A, O, C, and W, respectively, which are connected to suitable sources of fluid supply under appropriate pressure. All fluid supply conduits pass through a central valve stand V; and each conduit is provided with a suitable control valve V' and a pressure gauge K. Interposed in the acetylene conduit A between the valve stand V and the blowpipe B are a powder dispenser P, adapted to provide a continuous regulated supply of powdered metal to the acetylene stream, when desired; and a check valve D adapted to prevent flashbacks and powder clogging in the event that pressure builds up in a hole H being pierced. A shield S may be positioned about the opening of the hole being pierced in the rock R, to arrest the outward progress of spallings after ejection from the hole. The shield S may be provided with means for directing a water spray against the mouth of the hole being pierced, such as the perforated header E connected to a source of water supply. Each unit of the apparatus is light and may be transported easily.

Ordinarily, the intense heat necessary for carrying out the spalling process is supplied by the combustion of a fuel gas and a combustion-supporting gas, preferably acetylene and oxygen, respectively. In some cases, however, it has been found advantageous to produce an even more intense local heat by the oxidation of a comminuted solid, e. g. a metal, such as iron, aluminum, or mixtures thereof, which oxidizes exothermically. For this purpose, a powder dispenser P is provided so that a metal powder may be suspended uniformly and continuously in the acetylene stream, carried by the latter to the blowpipe tip, and directed against the rock surface to be pierced, where it immediately oxidizes with the simultaneous production of a great amount of localized heat. When operating without the use of the metal powder, as is usually the case, the dispenser may be left empty, it may be by-passed, or it may be entirely disconnected from the conduit A and the ends of the latter connected together. If a metal powder is used, it is preferred to choose a metal the oxide of which will not exercise a marked fluxing or softening action on the spallings.

The blowpipe B is also ordinarily supplied with water under pressure and with compressed air, either or both of which may be used for ejecting debris from the hole being pierced and for cooling the blowpipe, especially those parts of the blowpipe in the hole.

Briefly, our method of thermally working a compact mass of a heat-spallable substance, such as quartzite, comprises heating a selected portion of the substance to its spalling temperature by applying against a selected region thereof a flame from a suitable source means, such as a blowpipe, positioned close to such region, the flame being of sufficient heating intensity to cause particles to spall off in a finely-divided unfused condition. These spalled particles are promptly removed in the unfused condition from the vicinity of the flame, thereby leaving a cavity which is extended along a predetermined path by progressively advancing the flame source to heat and disintegrate, by spalling, new portions of the substance successively exposed within the cavity along such path, while progressively re-

moving the spalled particles from the vicinity of the advancing flame. During the advance of the flame, the flame source is constantly maintained sufficiently close to the newly exposed portions of the cavity and the spalled particles are concurrently removed sufficiently promptly and rapidly that the portions of the heat-spallable substance successively exposed to the heat are prevented from reaching their melting temperature.

More in detail, the process of thermal spalling as applied to rock piercing may be carried out as follows:

The gas mixture leaving the blowpipe is ignited and the gas and oxygen flows are so adjusted as to produce an extremely hot, and oxidizing high velocity flame at the tip of the tubular part of the blowpipe. Next, the blowpipe flame is directed upon the localized area or spot on the face of the rock to be pierced, with the blowpipe tip spaced a short distance therefrom so that the hottest portion of the flame is concentrated on and rapidly heats the rock surface. The blowpipe is held with the tip thus spaced until spalling of the rock surface begins. As particles fly off, a cavity comprising the initial section and mouth of a hole is produced into which, and into successive sections of which, as formed, the blowpipe is progressively advanced along a predetermined path, with the tip thereof always spaced a substantially constant distance from the bottom of the hole, the spallings being concurrently and progressively removed from the hole. This continuous spalling in advance of the blowpipe tip, and progressive advancing of the blowpipe to heat each newly exposed portion of the bottom surface of the hole, is continued until the desired depth has been reached, when the heating operation may be discontinued.

It sometimes happens that thin seams of non-spallable or difficultly-spallable rock are encountered during the progress of the piercing operation. When such a seam is encountered, some fusion or sintering may occur, and in this event the resultant slag of fused or sintered material should be removed in suitable manner from the hole before spalling is resumed. Also, the spallings themselves may sinter or fuse to an aggregate if the forward end of the blowpipe is not maintained sufficiently close to the newly exposed portions of rock at the bottom of the hole, and if the spallings are not removed sufficiently promptly and rapidly.

In most cases, the spallings produced in the process are cleared out of the hole simply by the stream of gaseous products of combustion flowing from the bottom of the hole toward the mouth thereof without the use of auxiliary ejecting means. This is most often true when a hole is being pierced either vertically upward or horizontally. Sometimes, most often when a substantially horizontal or downwardly-directed hole is being pierced, spallings may accumulate in the hole and seriously interfere with or even entirely stop the operation. In some cases, also, the spallings are of such size as to prohibit their being carried out of the hole by the exhaust gases. An important feature of this invention, therefore, is the provision for the regulatable and forcible ejection of spalling debris from a blast hole, regardless of the angle at which the hole is directed.

In the present process, spallings are forcibly ejected by discharging within the hole continuous or intermittent high-velocity, high-pressure

fluid streams at points adjacent to the bottom of the hole being pierced but spaced from the heating zone, and directing these streams away from the said zone upon the side walls of the hole and toward its mouth, thus supplementing the action of the gaseous products of combustion, and ejecting the spallings from the hole as fast as they are produced. The continuous discharge of the ejecting medium into a hole, simultaneously with the advance of the blowpipe, has been found particularly advantageous. In some cases, however, intermittent ejection of spallings is desirable.

Fig. 2 illustrates a type of piercing blowpipe which may be used in carrying out the spalling process of the invention, showing means by which high-pressure fluid streams may be discharged adjacent to the bottom of a blast hole for the ejection of spallings. In the form illustrated, the blowpipe comprises three elongated concentric tubes forming a central oxygen passage 11, an annular acetylene or acetylene-powder passage 12 around the oxygen passage 11, and around the acetylene passage 12 an annular passage 13 for the spalling ejection fluid which may also serve as a medium for cooling the blowpipe. Oxygen from the conduit O, and acetylene or an acetylene-powder mixture from the conduit A enter the blowpipe through nipples 14 and 15, respectively, are conducted separately through passages 11 and 12, respectively, and are discharged separately from the tip 16 where, on ignition, they produce a high temperature diffusion type of flame. The high-pressure ejection fluid, which may be water, compressed air, or a mixture of the two, enters through the nipple 17, passes forward through the annular passage 13, and is ejected at high velocity in a series of streams directed rearwardly and laterally outward at a sharp angle through a plurality of passages 18 provided around the circumference of the blowpipe. Passages 18 are located as close as possible to the tip 16 to insure the ejection of spallings as fast as they are formed while preventing the water, air, or other ejection fluid from discharging in advance of the blowpipe and so interfering with the progress of the piercing operation.

The dust hazard associated with the rock piercing process of the invention is relatively slight as compared with the commonly used drilling and cutting operations. Some substances spall in the form of small plates, others as coarse sand, and still others as fairly large dust particles, in contrast to the finely pulverized material resulting from mechanical drilling operations. The entire elimination of dust from the process of the invention, however, may be secured by the use of high pressure water streams as the medium for spalling ejection, thus moistening the spallings which then may be discharged from the blast hole without the production of any dust whatsoever. In some cases, as in the case of piercing very deep holes directed downwardly from the horizontal, water ejection is impracticable because the spalling action is stopped by water accumulating in the bottom of the hole. It is then necessary to use as the ejection medium either compressed air alone or a mixture of compressed air and water, and to provide for the complete removal of any dust by supplemental means as by directing a water spray upon the stream of spallings issuing from the mouth of the hole or by withdrawing the dust by means of a suction fan.

In addition to piercing blast holes the principles of the spalling process of the invention may be applied to the "springing" of blast holes. By "springing" is meant the producing of an enlarged chamber at the bottom of a blast hole, as is shown at H' in Fig. 3, to receive a larger charge of dynamite or other explosive at that point than would otherwise be possible. It has been found that if a blowpipe used for hole piercing, such as the one shown in Fig. 2, for example, is held in the hole with the tip at the point where springing is desired, rotation or agitation thereof will produce the desired result. In addition, the blowpipe may be very slowly retracted toward the mouth of the hole to produce a gradually enlarging chamber H' as shown in Fig. 3.

Another modification of the invention involves a melting operation. Most minerals and mineral-like materials, such as concrete, iron ore, and granite are composed of oxides in solid solution or in more or less heterogeneous admixture. For example, many commonly occurring minerals are composed principally of one or more of the oxides of aluminum, silicon, calcium, iron, titanium, or manganese in various combinations and proportions, as well as oxides of the alkali and alkaline earth metals such as the oxides of potassium, sodium, calcium, magnesium and barium. In addition, there may be combinations of these oxides with the acid anhydrides and sulfides. It has been found that materials of this nature may be melted by the application of heat at high temperatures, with the production of more or less viscous slags, and that thin, highly fluid slags may be formed by the addition of suitable fluxes in the ways more specifically described below. The term slag, as used herein, connotes the product resulting from melting minerals or mineral-like materials with the addition of a flux.

In general, the melting process is carried out by heating a selected localized area of a mineral to the melting temperature with the addition of a flux, promptly removing from the melting zone the slag so formed, and advancing the melting zone along a predetermined line. Some minerals will form a sufficiently fluid slag on melting to obviate the use of a flux. In the great majority of cases, however, a pasty slag is produced which can be removed from the melting zone only with the greatest of difficulty, if at all. With materials of this nature it is essential that a flux be added to the heated material to lower the melting point and to increase the fluidity of the slag to a point where it may be removed readily from the melting zone. Heating may be performed by means of gas flames providing a sufficiently high temperature. We prefer to use an oxyacetylene flame in combination with the exothermic combustion in oxygen of a finely comminuted material which will not only provide heat but will also serve as a flux-forming agent.

It will be understood, in view of the wide variety of mineral materials adapted for disintegration or piercing by this invention, that the suitability of a flux for a particular melting operation will depend upon the chemical nature of the mineral material being fluxed and, to some extent, upon the character and amount of metal oxide present as the result of the oxidation of any metal powder being utilized as a secondary heating medium. The prime requisite of the flux is a capacity to depress the melting point and increase the fluidity of the slags produced in the melting zone. On the other hand, the flux-forming agent must be capable of burning in oxygen

to produce the necessary high temperature conditions. Among materials which have been used successfully are iron, aluminum, manganese, zirconium, silicon, and mixtures thereof with one another.

Ordinary concrete is composed chiefly of the oxides of calcium, aluminum and silicon. The composition and the viscosity-temperature relations of a concrete aggregate are such that the addition of aluminum, aluminum oxide, silicon, or silica lowers the fluidity of the molten mass and causes formation of glassy slags which remain pasty over a wide temperature range and are removed with difficulty. By the addition of finely-divided calcium or calcium oxide, iron or iron oxide, or other basic oxides and oxide-forming materials, the slags produced are more crystalline and are more easily disintegrated by water and converted to a physical form in which they are readily removable from the melting zone. When using iron oxide as a fluxing agent, the same may be introduced into the melting zone in the form of metallic iron in which zone it is oxidized, thereby concurrently supplying additional heat for the melting operation.

Preferably the metal powder, with or without a preformed flux, is introduced into the melting zone in the form of a finely-divided suspension thereof in the stream of the fuel flowing thereto. It has been found that particles of the metal powder and flux having a fineness of between 200 and 300 mesh (Tyler) are especially suitable for use in the process. It is highly desirable to carry the flux to the melting zone in suspension in the fluid fuel, such as acetylene, in the interests of safety and continuity of operation.

The thinly fluid slag may be promptly removed from the melting zone by the flow of combustion gases alone. After leaving this zone, the slag may be ejected in the fluid condition or, alternatively, it may be solidified and disintegrated by chilling and ejected in the form of solid particles.

Apparatus as illustrated in Figs. 1 and 2, and as described above in connection with the spalling process, also may be used in applying the melting process of the invention.

In the preferred embodiment of the melting process of the invention, the powder dispenser P is filled with a comminuted exothermically oxidizable flux-forming substance. Acetylene is then admitted through the conduit A to the dispenser P in which it picks up a quantity of powder and with its suspended burden of particles then enters the blowpipe B from which it is applied against the material to be pierced.

Oxygen is admitted to the blowpipe B from the supply line O, and is likewise projected from the tip of the blowpipe toward the material to be pierced. The oxygen and acetylene-powder streams mix intimately by diffusion of one into the other after leaving the blowpipe and, on ignition, produce an extremely hot flame which heats a localized area of the material to a high temperature. The powder carried by the acetylene stream is oxidized, with the liberation of heat, simultaneously with the acetylene, and the metallic oxides formed flux the hot material, thus causing melting of the mass at a lower temperature than would be possible otherwise, and promoting the fluidity of the slag produced.

When forming a more or less deep passage within a massive mineral object, slag may be removed by a fluid discharged into the passage at a point slightly removed from the melting zone

and so directed as to eject slag from said zone.

In starting a pierce, the rock surface is melted by heating and fluxing at a selected point thereon to produce a crater containing molten slag. In the case of upwardly-directed, horizontal, and slightly downwardly-directed holes, the molten slag at first flows freely from the crater under the influence of gravity. In the case of holes directed either vertically downward or at sharp angles downward, the operation is so conducted that the molten slag is ejected from the crater by the pressure of the gaseous products of combustion.

To increase the depth of a hole, the melting zone is advanced into the body of material by progressively advancing the blowpipe into the crater to heat and flux the successively uncovered portions of said material. In most cases, the hole may be advanced to a very limited depth by removing the fluid slag through the agency of gravity and/or the pressure of the gaseous products of combustion. It has been found impossible, however, to pierce blast-holes to any practical depth without the use of auxiliary means for removing slag formed during the advance of the melting zone.

Of course, if desired, the piercing operation may be made intermittent, with periodic halts for mechanically clearing slag from the hole. It has been found most advantageous, however, to remove slag in such a way that the piercing process may be carried out as a substantially continuous operation. This is accomplished by discharging at high-pressure an auxiliary fluid, such as compressed air, at a point adjacent the advancing melting zone, but spaced therefrom, and directing the air rearwardly toward the mouth of the hole. In this manner, the pressure of the gaseous products of combustion flowing to the mouth is augmented by that of the compressed air, thereby forcing the fluid slag particles from the hole and keeping the latter clear of obstructions which might interfere with the advance of the blowpipe. For most purposes a continuous supply of compressed air is advantageously used for slag ejection as it not only furnishes the requisite slag-ejection pressure but also supplies oxygen to complete the combustion of combustible gases leaving the melting zone. By means of this secondary combustion, the hole is kept hot throughout its entire length to prevent premature slag solidification and the attendant difficulties in operation.

Although the drilling of holes has been emphasized in the above description, it will be recognized that the invention may be used wherever parts of massive mineral-like material are to be removed. Likewise, many variations of the specific procedures and means disclosed herein will occur to those skilled in the art. Accordingly, the invention is not limited to such specific procedures and means except as required by the state of the art.

We claim:

1. Method of piercing or otherwise cutting mineral and mineral-like masses which comprises continuously applying a high-temperature oxy-fuel flame at a localized heating zone on said mass whereby to separate a portion of said material at said zone; promptly removing said portion from the region adjacent said flame; advancing said flame in the direction of the cut; and moistening said separated material after removal from said flame region.

2. Method as defined in claim 1, wherein the

direction of the cut is into the mass of material to produce a hole therein, and wherein said separated material is moistened at the mouth of said hole.

3. A method as defined in claim 1, wherein the direction of the cut is into the mass of material to produce a hole therein, and wherein said separated material is moistened within such hole before discharge therefrom.

4. A method of thermally working a compact mass of a heat-spallable substance, which method comprises heating a selected portion of said substance to its spalling temperature by applying against a region thereof a flame from suitable source means positioned close to said region, such flame being of sufficient intensity to cause particles of said substance to spall off in a finely-divided unfused condition; promptly removing the spalled particles from the vicinity of the flame, thereby forming a cavity; extending such cavity along a predetermined path by progressively advancing said source means to heat and disintegrate solely by spalling new portions of said substance successively exposed within said cavity along such path while progressively removing the spalled particles from the vicinity of the advancing flame; during such advance of the flame, constantly maintaining said source means sufficiently close to the newly exposed portions of such cavity and concurrently removing said spalled particles sufficiently promptly and rapidly that the portions of said substance successively exposed to the heat are prevented from reaching their melting temperature; and moistening with water the finely-divided spalled particles during their removal from the vicinity of the advancing flame, to prevent their distribution as dust into the atmosphere.

5. A method of thermally piercing a hole in a compact mass of a heat-spallable mineral or mineral-like substance, which method comprises applying against a selected area on a face of said mass a flame from suitable source means positioned close to said face, such flame being of sufficient intensity to heat a portion of said substance to its spalling temperature and cause particles of said substance to spall off in a finely-divided unfused condition to form the initial section and mouth of such hole; progressively advancing said source means and said flame into said initial section of such hole, and into successive sections of such hole as formed, to similarly heat successive newly-exposed portions of said substance and progressively disintegrate them solely by spalling, thereby forming successively deeper portions of such hole; concurrently ejecting the spalled particles from such hole by at least one stream of water flowing rearwardly from the vicinity of the advancing flame toward the mouth of such hole, such water moistening said spalled particles to prevent their distribution as dust into the atmosphere; and, dur-

ing the advance of such flame, constantly maintaining said source means sufficiently close to said successive newly exposed portions and concurrently removing said spalled particles sufficiently promptly and rapidly that the portions of said substance exposed to the heat are prevented from reaching their melting temperature.

6. A method of thermally working a compact mass of a fusible mineral or mineral-like substance, which method comprises applying a high temperature flame at a localized heating zone on said mass while introducing into said zone fluxing material, thereby melting a portion of said mass and forming a thinly fluid slag; removing said slag in the fluid condition from the vicinity of the flame, thereby forming a cavity; extending such cavity along a predetermined path by progressively advancing said flame to heat successive zones and disintegrate, by melting, successive portions of said substance within said cavity along such path, while introducing fluxing material into such successive zones and removing the slag in the fluid condition from the vicinity of the advancing flame; and progressively chilling, solidifying, and moistening said slag, immediately after removal from the vicinity of such flame, by directing water into intimate contact therewith within said cavity, the chilled and moistened slag thereafter being promptly removed from the chilling zone in the solid condition.

7. A method of thermally working a compact mass of a heat-spallable substance, such as quartzite, which method comprises heating a selected portion of said substance to its spalling temperature by applying against a selected region thereof a flame from suitable source means positioned close to said region, such flame being of sufficient heating intensity to cause particles of said substance to spall off in a finely-divided unfused condition; promptly removing such spalled particles in the unfused condition from the vicinity of the flame, thereby leaving a cavity; extending such cavity along a predetermined path by progressively advancing said source means to heat and disintegrate solely by spalling new portions of said substance successively exposed within said cavity along such path while progressively removing the spalled particles from the vicinity of the advancing flame; and, during such advance of the flame, constantly maintaining said source means sufficiently close to the newly exposed portions of such cavity and concurrently removing said spalled particles sufficiently promptly and rapidly that the portions of said substance successively exposed to the heat are prevented from reaching their melting temperature.

ROBERT B. AITCHISON,  
CHARLES W. SWARTOUT,  
VIRGIL C. WILLIAMS.