My invention relates to bits of the character employed in drilling wells and relates in particular to a bit adapted to dig by a combined scraping and pounding action.

The rotary system of well drilling to which my invention particularly relates employs drilling bits of three general classifications: the scraping type, which includes fish-tail bits; the roller or rolling type, such as roller-rock bits; and the combined scraping and rolling type, such as disc bits and gyrating bits. The most used of the above types of bits is the scraping type having one or more blades which are steadily pressed against the bottom of the hole during rotation of the bit by the drill pipe, removing the formation by a slicing or scraping action. In the use of this type of bit hardness of the formation can be overcome efficiently only by placing hard metal cutting elements at the cutting edges of the bit. It is evident that the success of all scraping bits depends entirely on the hardness of the metal or metallic insert at the cutting edges of the bit.

My present invention comprehends a well drilling bit having a cutter adapted to strike the bottom formation of a well being drilled with a hammer-like action, the hammering effect obtained thereby producing a splitting, cracking, chipping, and crushing of the formation so that the resistance of the formation removed by a scraping operation is very materially reduced.

The invention also comprehends a mechanism adapted to apply energy stored in the circulating mud fluid to impart blows to a vertically movable cutter carried on a bit body suspended by means of a drill pipe within a well being drilled.

It is an object of the invention to provide a well drilling device having a chopping cutter at its lower end and a hydraulically operated chopping mechanism situated adjacent to the chopping cutter and being adapted for actuation by the drilling fluid or mud employed in the rotary method of well drilling.

A further object of the invention is to provide a well drilling device including a body adapted to be suspended and rotated in a well by means of a string of drill pipe, this body having a scraping cutter thereon adapted to scrape the bottom formation of the well, a reciprocable cutter adapted for a hammering or chopping action on the bottom of the well and a hydraulically operated device for periodically and forcibly bringing the reciprocable cutter into engagement with the bottom formation of the well so as to disintegrate the formation by a chopping, splitting, and crushing action which will enable its more readily removal by the scraping cutters of the drilling device.

A further object of the invention is to provide a novel, simple and effective hydraulically operated mechanism for accomplishing the desired hammering action hereinabove set forth.

Further objects and advantages of the invention will be made evident in the following part of the specification.

Referring to the drawings which are for illustrative purposes only,

Fig. 1 is a vertically sectioned schematic view.

Fig. 2 is an enlarged vertical sectional view of a preferred embodiment of my invention, this view showing the parts of the mechanism at the beginning of a hammering stroke.

Fig. 3 is an enlarged vertical section of the lower portion of the bit shown in Fig. 2, this view showing the mechanism in position at the end of a hammering stroke.

Fig. 4 is a view similar to Fig. 3, but drawn to smaller scale, showing disposal of the mechanism during the lowering and raising of the bits within a well.

Fig. 5 is a bottom plan view of Fig. 3.

Fig. 6 is a cross section view on the plane represented by line 6—6 of Fig. 2.

Fig. 7 is a fragmentary vertical sectional view showing a form of my invention having a single cutter adapted to accomplish both the hammering and the scraping operations featured by my invention.

Fig. 8 is a fragmentary vertical sectional view showing an alternative form of my mechanism which may be employed in the practice of the invention.
Fig. 9 is a sectional view of an embodiment of my invention employing a hammer member which is impelled downwardly by the flow of drilling fluid and lifted by means of a cable.

Fig. 10 is a cross section on a plane represented by the line 10—10 of Fig. 9.

Fig. 11 is a cross sectional view similar to Fig. 9 but showing a valve for closing the passageway of the hammer member.

Fig. 12 is a cross section on a plane represented by the line 12—12 of Fig. 11.

Fig. 13 is a vertically sectioned view showing a form of my invention in which the hammer is raised hydraulically.

Fig. 14 is a section on a plane represented by the line 14—14 of Fig. 13.

Fig. 15 is a vertically sectioned view similar to Fig. 13 but showing an automatic valve mechanism for controlling the operation of the hydraulically actuated hammer.

Fig. 16 is a cross section on a plane represented by the line 16—16 of Fig. 15.

Fig. 17 is an elevational view showing a means for raising and lowering a cable such as employed in the forms of my invention shown in Figs. 9, 11, and 13.

For the purpose of indicating the general utility of my invention I have in Fig. 1 shown a preferred form of my drill bit 11 suspended and rotated within a well 12 by means of a string of drill pipe 13 which is operated in accordance with standard practice by means of a rotary table 14 and is suspended by a block and tackle system generally indicated at 15. A mud pump 16 pumps mud under pressure through a rotary hose 17 into the upper end of the drill pipe 13, this rotary mud or drilling fluid passing downwardly through the drill pipe 13, and the bit 11 and being discharged into a hole or well 12 through suitable openings at the lower end of the bit 11.

The preferred form of my invention disclosed in the drawings consists of a hollow body 18 having operating mechanism therein. The hollow body 18 consists essentially of an outer tube or cylindrical wall 20, the upper end of which is threaded, as indicated at 21, so as to be screwed on to the lower end 22 of a drill collar 23 which forms the lower end of the string of drill pipe 13, and the lower end of which is externally threaded at 24 to receive a scraping cutter 25 having a plurality of scraping blades 26 and being provided with a central bore 27 of approximately the same diameter as the interior of the tube 20. Projecting downwardly from and communicating with the drilling fluid passage 28 of the member 23 is a tubular member 30 of approximately half the diameter of the tube 20. This tube 30 has a plurality of openings 31 therein through which drilling fluid received from the passage 28 may enter the interior of the tube 20, as indicated by arrows 32. The lower end 33 of the tube is constricted so as to fit closely around an upper valve stem 34 which projects from a valve 35. On the upper end of the upper valve stem 34 is a sleeve or nut 36 adapted to receive the upward thrust of a spring 37 which surrounds the stem 34 and rests on the radial wall formed by the lower end 33 of the member 30.

Immediately below the valve 35 within the tube 20 is a ram or hammer member 38 having a vertical passage 40 therethrough, and packing means 41 near its upper end, and being diametrically reduced throughout the greater portion of its lower extension so as to form within the tube 20 an annular space 42 in which a ram spring or hammer lifting spring 43 is received. The spring 43 rests on an annular wall 44 which projects upwardly from the body 45 of a reciprocable cutter mechanism 46 which projects within the lower end of the tube 20 and is retained therein by retaining means 47 which may consist of a plurality of steel balls which engage an annular groove 48 in the body 45 and an annular groove 50 formed between the lower end of the tube 20 and the body portion of the cutter 45. The body 45 has packing means 51 near its upper end and is provided with a central opening 52 which communicates with the upper end of the body 45 and with discharge orifices 53 at the lower end of the body 45. A plurality of chopping blades 54 are formed radially on the lower end of the chopping cutter 46, and as shown in Fig. 5 these blades 54 may be three in number and may extend radially to the full diameter of a circle 55 defined by the scraping blades 26 which may be also three in number. The scraping cutter 25 has a plurality of radial slots or notches 56 through which the chopping blade 54 may extend radially as indicated in Figs. 1 and 5, these slots or notches 56 being placed in positions intermediate the scraping blades 26.

The valve 35 has a lower conical formation 58 which extends downwardly into a conical counterbore 59 at the upper end of the passage 40 of the member 38, and projecting downwardly from the conical formation 58 is a lower valve stem 61 having its lower end 62 projecting slightly below the lower end 63 of the member 38. The chopping cutter body 45 also includes an anvil 64 at its upper end and in a position to be engaged by the lower end 62 of the lower valve stem 61 and the lower end 65 of the ram or hammer member 38. The anvil 64 is provided with openings 65 through which drilling fluid may flow from the space above the anvil into the passage 52 of the chopping cutter 46.

In Fig. 9 the well drilling device 11 is shown resting on the bottom 67 of the well 12 and the reciprocating parts of the mechanism.
anism are shown in position ready to start a hammer stroke of the ram or hammer 38. The upper end of the member 38 is shown in engagement with the valve 35 so that the upper end of the passage is thereby closed thus preventing drilling mud from flowing through the passage 40 and causing the pressure and velocity of the drilling mud to be exerted against and applied to the member 38 whereby to move the member 38 downwardly in the tube 20 at relatively high velocity and under great pressure. At the lower end of its downward or hammer stroke the member 38 strikes the anvil 64 of the chopping cutter 46 and drives the cutter 46 downwardly with great force against the bottom 67 of the well. Just before engagement of the lower end of the hammer 38 and anvil 64, the lower end 62 of the lower valve stem 61 is engaged and stopped by the central portion of the anvil 64. As the hammer 38 continues to move downwardly by engagement with the anvil 64, the upper end thereof is removed from the valve 35, thus releasing the valve 35 and allowing it to be moved upwardly by the spring 37 into position against the lower end 63 of the member 38. The lower end 63 of the member 38 forms a stop for limiting the upper movement of the valve 35 and the central portion of the anvil 64 provides a stop for limiting the downward movement of the valve 35. In Fig. 3 the lower end 63 of the member 38 is shown in engagement with the anvil 64 at the completion of a hammer stroke and the valve 35 is shown in a position against the stop 33 into which position the valve 35 upon its release has been lifted by the spring 37 shown in Fig. 2. At this time drilling fluid flows downwardly around the valve 35 as indicated by arrows 70 and passes downwardly through the central passage 40 of the member 38, pressure against the upper and lower ends of the member 38 being equalized to such an extent that the member 38 may be moved upwardly by the lifting spring 43. Under upward pressure of the spring 43 the member 38 then moves from its position of Fig. 3 toward the valve 35, or toward the position in which it is shown in Fig. 2. During this upward movement of the member 38 the drilling fluid is flowing downwardly through the body 18 and the passages 40 and 52 therewithin, this flow of drilling fluid being at a constant velocity and impelled by the momentum of the body of fluid which is moving downwardly through the string of drill pipe 13. When the member 38 has moved upwardly to a sufficient extent the valve 35 will make engagement with the upper end thereof and will close the passage 40 thereby throwing the ram or hammer 38 into the downwardly moving flow of drilling fluid and producing another hammer stroke. At the end of this consecutive hammer stroke the valve 35 is released by engagement with the anvil 64 in the manner previously described and a consecutive upward stroke of the ram or hammer 38 is then performed and as long as a flow of drilling fluid is continued through the drilling device, the action of the reciprocating parts will be maintained.

Each blow of the member 38 produces a penetrating, splitting, cracking, and crushing of the formation constituting the bottom 67 of the well 12 by the chopping blades 54 of the chopping cutter 46. The upper portion or surface structure of the bottom 67 is thereby disintegrated or partly disintegrated to such an extent that it may be scraped off by the scraping cutter 26 with comparative facility.

The anvil 64 is of removable character so that it may be replaced by another anvil of greater or lesser height so as to increase or decrease the length of stroke and consequently the force of the ram or hammer 38.

With reference to Fig. 4, it will be noted that the annular channel 45 in the body 44 of the chopping cutter 46 is of much greater vertical width than the diameter of the steel balls which constitute the retaining means 47. Therefore, when no lifting force is exerted against the lower end of the chopping cutter 46 it may drop downwardly from the position in which it is shown in Fig. 2 to the position in which it is shown in Fig. 4, the downward movement being limited by the vertical width of the annular channel or groove 48. The import of this construction is that during disengagement of the drill bit 11 with the bottom of the well the chopping cutter 46 will rest in the lowered position in which it is shown in Fig. 4 and the parts 38, 42, 44, and 64 which are supported on the upper end of the chopping cutter 46 will assume a corresponding lowered position in which the lower end of the member 38 will be downwardly withdrawn from the valve 35 so that there will be no possibility of the valve closing the passage 40 of the member 38 and thereby causing reciprocation of the member 38 during the raising or lowering of the drilling device within a well.

This expedient makes it possible to circulate drilling fluid through the drill pipe and the drill bit 11 during the raising and lowering of the drilling device without reciprocating the hammering mechanism of the drilling device. As soon as the bit 11 strikes the bottom and the chopping cutter 46 is forced upwardly relative to the body 18 into the position in which it is shown in Fig. 2, reciprocating action of the member 38 will immediately start and on rotation of the drill bit 11 a combined scraping and chopping drilling effect will be produced.

In Fig. 7 I show the lower portion of a tubular member 80 forming part of a bit body
18, having reciprocating mechanism therein of the character shown in Figs. 2 to 4.

In the lower extremity of the tubular member 80 a single cutter 81 is secured. This cutter has a body 82 extending within the tubular member 80 and a plurality of blades 83. By use of retaining means 84 the cutter 81 is secured in vertically movable relationship to the tubular member 80 so that by use of the hammering mechanism contained in the upper portion of the tubular member 80 the cutter 81 may be driven against or into the bottom formation of a well in an intermittent or reciprocating manner. If desired, the single vertically reciprocable cutter 81 may by interengaging means such as a key and slot be rotated by the tubular member 80 whereby a scraping and chopping action may be obtained by the use of a single cutter instead of a combination of scraping and chopping cutters, as shown in Figs. 2 to 4.

Although I have shown the preferred form of valve mechanism in Figs. 2 to 4 of the drawings, other valve mechanisms may be employed to accomplish automatic reciprocation of a hammer member. As shown in Fig. 8 a valve 85 may be mounted on a valve stem 86 which projects downwardly through a passage 87 in a hammer or ram 88, it being understood that the lower end of the stem 86 engages a stop when the member 88 reaches the lower extremity of its hammer stroke and is thereby released from closure position relative to the upper end of the passage 87.

In this form of valve mechanism the valve 85 has no upwardly extending stem and is lifted into raised position relative to the member 88 as indicated by dotted lines 90, by a spring 91 situated in a recess or counterbore 92 in the upper end of the member 88.

When the valve 85 is in the raised position indicated by the dotted line 90 the member 88 will be moved upwardly by a lifting spring 93 so that the valve 85 will move toward an end member 94 secured in the upper end of the tube 95 of the drilling mechanism. Upward movement of the hammer or ram 88 will then continue until the valve 85 is again closed against the upper end of the member 88 and a hammer stroke of the mechanism is started.

In Fig. 9 I have shown a very simple form of bit having a hammering device incorporated therein, which hammering device includes a tubular hammer adapted to be raised by a cable which extends upwardly from the drilling tool and which is lowered through a hammering stroke partly due to its own weight and partly due to frictional engagement with the flow of drilling fluid which is traveling downwardly at high velocity through the drilling tube.

This embodiment of my invention consists essentially of a drill body 100 having a pass-
by hydraulic means consisting of the drilling fluid, as previously described. By suitable reciprocation of the cable 115 a desired reciprocation or hammer action of the hammer 114 is accomplished.

The form of my invention shown in Figs. 11 and 12 includes a body 130 having a cutter member 131 secured in its lower end in vertically reciprocable relationship as described relative to Fig. 9. A hammer 132 is provided in the chamber 133 of the drilling device, which hammer is similar to the hammer 114 but differs therefrom by the use of a valve seat 134 at the upper end of its axial opening 135 and a valve member 136 secured to the lower end of a cable 137 which projects upwardly through a passage 138 to a cable reciprocating mechanism. The valve member 136 has a limited vertical movement relative to the hammer 132 and is contained in a yoke or gauge 140 which is secured to the upper end of, and forms part of the hammer 132. This gauge 140 has a concentric sleeve 141 through which the cable 137 passes into engagement with the valve 136. The sleeve or guide for the cable is supported in the gauge structure 140 by radial webs 142 which project inwardly from the annular wall 143 of the gauge, the lower portions 144 of these webs serving as guides for the valve member 136. When the cable 137 is pulled upwardly the valve member 136 is raised from the seat 134 into engagement with the lower end of the guide sleeve 141. By continuing the upward movement of the cable 137, the valve member 136 may be employed to lift the hammer 132 into raised position in the chamber 133.

During the raising of the hammer 132 as shown in Fig. 11 drilling fluid passes downwardly through the gauge 140 as indicated by arrows 145, through the axial passage 135, through an opening 146 in the cutter member 131 and is discharged through orifices 147 as indicated by an arrow 148. When by use of the cable 137 the hammer 132 is raised to the upper end of its stroke, the cable 137 is released and the valve member 136 is thereupon allowed to drop into engagement with the valve seat 134, closing the upper end of the axial passage 135 of the hammer 132 so as to have the effect of throwing the hammer 132 into the stream of drilling fluid which is traveling downwardly through the body 130, and resulting in the hammer 132 being carried forcibly into hammer-blow engagement with the upper end of the cutter member 131.

In this form of the invention the hammer is raised mechanically and is hydraulically actuated through its downward stroke. By proper reciprocation of the cable 137 consecutive actuations of the hammer 132 may be accomplished.

In Figs. 13 and 14 I show an embodiment of my invention in which a hammer 150 is moved both upwardly and downwardly by hydraulic action and in which a valve 151 controlled by a cable 152 is employed to control the hydraulic action. The hammer 150 has an upper tubular portion 153 of relatively small diameter and a lower cylindrical body portion 154 of relatively large diameter. The upper portion 153 slides through packing means 155 carried in the drill body 156, and packing means 157 is provided on the head 154 for engagement with the inner surface of the cylindrical wall 158 of the drill body 156, there being openings 160 through the upper portion of the wall 158, these openings 160 being situated immediately below the packing means 155. When the cable 152 is drawn upwardly so as to raise the valve 151 from a cooperating seat 162 in the upper end of the hammer 150 drilling fluid under pressure flows downwardly through the axial opening 163 of the hammer 150, as indicated by arrows 164, into the space 165 below the hammer 150. The drilling fluid issues through discharge openings 166 in a cutter member 167 at a rate of flow which is controlled by the size of an opening 168 in the upper end of the cutter member 167. This opening 168 is of such size that the fluid pressure within the chamber 165 acting against the relatively large lower end of the hammer 150 will be sufficient to overcome the pressure of fluid acting on the relatively small upper end of the hammer in downward direction thereby causing the hammer 150 to move upwardly into raised position within the drill body 156.

During the upward movement of the hammer 150 fluid accumulated in the annular space 170 below the packing means 155 is forced outwardly into the wall through openings 160. When the hammer 150 is in a raised position closing of the valve 151 relative to the valve seat 162 is accomplished by lowering the cable 152, and immediately upon closing of this valve 151 the downwardly moving drilling fluid actuates the hammer downwardly into engagement with the cutter member 167. The subsequent raising of the valve 151 from engagement with the valve seat 162 by raising the cable 152, releases the fluid pressure in the chamber 172 above the packing means 155 and permits the drilling fluid to again flow downwardly through the axial passage 153 of the hammer 150 and into the chamber 165, where the drilling fluid will again build upon in pressure and volume so as to produce a consecutive upward movement of the hammer 150.

In this form of the invention disclosed in Figs. 13 and 14, proper reciprocation of the valve member 151 by use of the cable 152 controls the hydraulic action within the drilling device, which will produce a continuous reciprocating, hammering operation of the
hammer member 150 whereby to produce consecutive hammer blows for the purpose of driving the rotating or non-rotating cutter into the earth formation forming the bottom of the well being drilled.

The diameters of the upper and lower ends of the hammer member 150 are proportioned relative to the flow retarding effect of the opening 168 to accomplish the desired pressures on the upper and lower ends of the hammer member 150 when the valve 151 is opened and closed to accomplish hydraulically the raising and lowering of the hammer, substantially as previously described.

In the forms of my invention shown in Figs. 9 to 14 inclusive the hammer means is controlled from the surface of the ground; and for completing the disclosure of a complete operative means, I show the surface apparatus in Fig. 17. The cable 115 or 159 may have a rod 210 secured to the upper end, which extends through a stuffing box 211 of a swivel 212. The rod and cable connected thereto are reciprocated by a beam 214.

The form of my invention shown in Figs. 15 and 16 employs the principles of hydraulic reciprocation disclosed relative to Figs. 13 and 14, but in this last form of the invention the cable actuated valve mechanism 180 consisting of a valve body proper 181 adapted to engage the valve seat 182 at the upper end of the axial passage 183 of a hydraulically reciprocated hammer 184, and a spring 185 which exerts a continuous pressure tending to raise the valve 181 from the seat 182. When the valve 181 is in raised or open position relative to the seat 182, the pressure exerted in the lower chamber 186 and against the relatively large lower end 187 of the hammer 184, being greater than the pressure exerted against the relatively small upper end 188 of the hammer 184, produces an upward movement of the hammer, carrying the valve member 181 and the upper end 188 into the respective positions indicated by dotted lines 190 and 191, at which time the spider arms or guide members 192 engage the plug or body 193 forming the upper end of the drilling device so that further upward movement of the valve 181 is thereby prevented and so that the continued upward movement of the hammer member 184 will carry the valve seat 182 into engagement with the valve 181. Upon closing of the valve 181, the fluid flowing downwardly into the upper chamber 194 will cause the hammer 184 to be forced downwardly at relatively high velocity and under considerable pressure, the pressure of the fluid in the chamber 194 maintaining the valve 181 in closed position relative to the seat 182, as shown in full lines in Fig. 15.

When the hammer member 184 reaches a point near engagement with a cutter member 195 reciprocally held in the end of the drilling device, such as shown in full lines in Fig. 15, the spider arms 192 of the valve 181 engage in an annular shoulder 196 so that further downward movement of the valve 181 is prevented thereby. The hammer member 184 is carried by momentum into engagement with the cutter member 195 and the valve seat 182 is withdrawn from engagement with the valve 181, the spring 185 then holding the valve 181 in open position, whereupon the drilling fluid will flow through the axial passage 183 of the hammer member into the lower chamber 186, where the pressure there will operate to lift the hammer member through a return stroke.

In this embodiment of the invention an opening 197 in the cutter member 195 is so proportioned relative to the areas of the upper and lower ends of the hammer member 184 that the pressure required for raising the hammer member 184 will be produced in the chamber 186 when the valve 181 is open. The automatic opening and closing of the valve member 181 at the respective ends of the downward and upward movements of the hammer member 184 produces a continuous reciprocation and causes the hammer member 184 to strike consecutive hammer blows on the cutter member 195.

In the disclosure the invention is shown mechanically and hydraulically actuated and fully hydraulically actuated. From this it will be perceived that the invention includes not only a drilling device having a hammer hydraulically actuated by the drilling fluid but also a drilling device in which a hammer is operated partly by springs and hydraulic action or by fully mechanical means, such as a cable extending to the derrick of the well drilling equipment.

Although I have shown simple and practical forms of my invention, it is recognized that parts or elements thereof may be replaced by other parts or elements by which substantially identical results may be accomplished; therefore, it is to be understood that my invention is not limited to the details of the foregoing disclosure but should be accorded the full scope of the following claims.

I claim as my invention:

1. A drilling device of the character described, including: a body adapted to be secured to the lower end of a string of drill pipe, said body having passage means for conducting a flow of drilling mud from said drill pipe to the lower portion thereof; a vertically reciprocable cutter mechanism at the lower end of said body; a reciprocable member in said body adapted to engage and disengage said cutter mechanism, said member having a vertically directed opening therethrough, through which the flow of drilling mud passes; means for yieldably forcing said member upwardly; and valve means adapted
to periodically close said opening through said member so as to cause said reciprocable member to move downwardly with the flow of drilling mud through said body and forcibly engage said cutter mechanism.

2. A drilling device of the character described, including: a body adapted to be secured to the lower end of a string of drill pipe, said body having passage means for conducting a flow of drilling mud from said drill pipe to the lower portion thereof; a vertically reciprocable cutter mechanism at the lower end of said body; a reciprocable member in said body adapted to engage said cutter mechanism, said member having a vertically directed opening therethrough, through which the flow of drilling mud passes; means for yieldably forcing said member upwardly; a valve adapted to seat against the upper portion of said member so as to close said opening; an upper stop for said valve for holding said valve in position to engage said member at the upper end of the movement of said member in said body; means for yieldably forcing said valve downward said upper stop; and a lower stop for engaging said valve and moving it from closing position relative to said opening when said member approaches the lower end of its movement in said body.

3. A drilling device of the character described, including: a tubular body adapted for attachment to the lower end of a drill pipe; a cutter element at the lower end of said body, having a part projecting within said body; a hammer member vertically movable in said body, said hammer member having an opening therethrough for passage of drilling fluid; a valve for closing the upper end of said opening; an upper stem extending upwardly from said valve; a hollow member projecting downwardly within said body and around said upper stem, said hollow member providing a stop for limiting the upward movement of said valve; means engaging said stem for yieldably forcing said valve upwardly; a spring for moving said hammer member upwardly into engagement with said valve when said valve is in raised position, such engagement causing said hammer member to move downwardly with the flow of drilling fluid through said body so as to strike said part of said cutter element; a lower valve stem extending downwardly from said valve and through said passage of said hammer member; and a lower stop adapted to be engaged by said lower valve stem whereby to release said valve as said hammer member approaches said cutter element.

In testimony whereof, I have hereunto set my hand at Los Angeles, California, this 17th day of April, 1930.

JOHN A. ZUBLIN.