

**A NEW SAMPLING SYSTEM FOR OBTAINING RELATIVELY  
UNDISTURBED SAMPLES OF UNCONSOLIDATED COARSE SAND AND  
GRAVEL**

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## INTRODUCTION

In recent years, considerable emphasis has been placed on the characterization of spatial variations in aquifer properties in order to understand and predict the effects of this heterogeneity on contaminant transport. Contaminant movement in the subsurface is controlled by physical, chemical and biological processes. We cannot begin to solve the chemical and biological components of this puzzle until we have an understanding of the physical processes controlling ground water flow. Usually, the major uncertainty in the physical description is the heterogeneity in aquifer parameters. Ideally, aquifer heterogeneity should be studied at various scales appropriate for the necessary predictions. The focus of this paper is on the study of aquifer heterogeneity through the collection of core samples. It is quite difficult to obtain intact cores of unconsolidated saturated coarse sand and gravel. However, there are many sites in Kansas and elsewhere where sands and gravels are major sources of groundwater and have become or have the potential to become polluted due to disposal of wastes in or near them. It is essential that we have techniques for studying heterogeneity in these aquifers. Numerous investigators have described techniques for obtaining samples in unconsolidated materials (Parsons, 1960; Patterson et al., 1978; Munch and Killey, 1985; Zapico et al., 1987, Hess and LeBlanc, 1987; Leach et al., 1989). However, when sampling at depths greater than about 10 meters and in the absence of any significant amount of fine material, the success of these samplers is very spotty. At the KGS, we tried all of these techniques and were not satisfied with the recovery rate (Butler et al., 1989). That experience led us to develop the new sampler designs and improved drilling procedures, and that is the subject of this paper.

## THE GEMS SITE

The KGS in 1988 initiated a project to study heterogeneity in alluvial aquifers. The objectives of this project are to characterize the heterogeneity of a site as completely as possible, to develop new methodologies and techniques for quantifying heterogeneities in unconsolidated sand and gravel aquifers, and to study the effects of heterogeneity at various scales. The Geohydrologic Experimental and Monitoring Site (GEMS) of the KGS is the field area that is being used in this work. Figure 1 is a sketch of the two areas that comprise the research site. The work of this project is being carried out in the area marked A on Figure 1. Area A of GEMS consists of approximately 70 feet of Kansas River alluvium of Pleistocene age which overlies consolidated geologic formations of Pennsylvanian age. The alluvial facies assemblage consists of approximately 35 feet of clay and silt overlying about 35 feet of sand and gravel. The stratigraphy is a complex system of stream-channel sand and overbank deposits. A series of piezometer nests have been established at the site. A typical cross-section through one of these nests is shown in Figure 2. A typical nest consists of 2-inch pvc wells completed at 10 foot intervals with screens of approximately 2.5 feet in length. Each nest also contains a 2-inch well fully screened through the sand and gravel section. One nest contains a bedrock well; others may be installed later. Figure 3 is a blow-up of Area A which shows a high capacity well and three nests of piezometers that have been established. To date, 23 wells have been drilled at this site. Most are in the three nests shown in Figure 3. Some single wells have been drilled and other nests are slowly being established.

## DRILLING PROCEDURE

All except one of the wells at GEMS have been installed with hollow-stem auger techniques. We used auger flights with 3 1/4 inch inside diameter and 6 5/8 inch outside diameter. A typical hollow stem auger string is shown in Figure 4 (CME, 1987). A typical installation would proceed by drilling to about 35 feet with a knock-out plate installed in the auger head in place of a pilot bit (Perry and Hart, 1985; Hackett, 1987). Heaving sands or sandblows (Perry and Hart, 1985; Keely and Boateng, 1987; and Hackett, 1987) are a severe problem at this site below about 35 feet, after entering the sand and gravel sequence. The problem of heaving sands is illustrated in Figure 5. It is absolutely essential to maintain greater hydrostatic pressure inside the auger flights than in the formation when dealing with heaving sands (Hackett, 1987). If the procedure of maintaining a greater head in the augers is not followed at all times, especially any time tools are moved within the flights, several feet of hole may be lost quickly and any hope of obtaining an undisturbed sample at that location is lost. At GEMS, we are mainly interested in the sand and gravel of the lower 30-35 feet. Below 35-40 feet, we typically want to obtain continuous samples. The auger flights are five feet in length, so we sample the five feet in front of the auger head before drilling down the next flight. In order to take a sample, the pilot bit must be withdrawn and the sampler inserted and driven forward of the auger head. Figure 6 summarizes the steps involved in obtaining a sample. The sampler is designed to obtain a five foot sample. During removal of the pilot bit and retrieval of the sampler there is great potential to experience heaving sands, so the auger flights must be kept full of formation water.

## **IMPROVED SAMPLER DESIGN AND ASSOCIATED EQUIPMENT**

Workers at the University of Waterloo (Zapico et al., 1987) have shown that recovery percentages in saturated sands and gravels can be significantly increased by a vacuum-maintaining piston arrangement set in a plastic or aluminum liner in a core barrel. Their design is shown in Figure 7. The Waterloo group and others have reported nearly 90 percent recovery in some cases using drilling mud inside the auger flights to help hold the sample in place during retrieval.

In the spring of 1988, a sampler, based on the Waterloo design, was constructed at the KGS. This sampler was fairly successful in aquifer sections containing significant amounts of fine material. However, in the deeper sections of coarse sand and gravel, recovery ranged from 0-70 percent and was generally unsatisfactory. Unsatisfactory recoveries were obtained even when using the procedure of disconnecting the drill rods and recovering with the wireline as described by others (Zapico et al., 1987; Munch and Killey, 1985). When drilling muds were used inside the auger flights (Zapico et al., 1987), we were able to obtain recovery percentages near 90 percent. However, the whole procedure is very delicate and any misstep or vibration may cause significant or complete loss of the sample. The introduction of drilling muds is a worrisome element of the sampling procedure, as the mud may alter ground water chemistry and may affect the porosity and hydraulic conductivity of the recovered cores.

## KGS FINGER SAMPLER

The decision was made to modify the sampler design in an attempt to obtain higher recovery percentages without the addition of drilling muds. In the summer of 1988, the drive shoe for a modified sampler was constructed at the KGS (Butler et al., 1989). The modified sampler (the KGS finger sampler) uses an external movable sleeve on the drive shoe that controls the movement of retractable spring steel fingers that are stored inside the shoe walls as the sampler is advanced and are deployed into the sampler throat as the sampler is retrieved. The design is shown in Figure 8. The external sleeve is attached to the spring steel fingers and is moved by frictional forces of the drive shoe against the surrounding sediments. When the sampler is being driven, forward frictional forces cause the sleeve to be forced to the rear, retracting the steel fingers into the walls of the drive shoe. As one begins to retrieve the sampler, the frictional forces reverse direction causing the sleeve to slide forward, deploying the fingers into the throat of the sampler. Figure 9 shows a picture of the constructed drive shoe and a view down its throat with the fingers deployed. When the steel fingers deploy with the first upward movement of the core barrel during retrieval, the percentage of recovery has been very high. However, the friction exerted by the surrounding sediments does not always immediately trigger the movement of the fingers, so lower recoveries on the order of 60-70 percent are very common in this case. Another shortcoming of this sampler drive shoe design is that it must be taken apart and cleaned periodically.

## KGS BLADDER SAMPLER

In late 1989 and early 1990, we attempted to design a sampler that would be more reliable and need less maintenance, while not requiring the use of drilling mud. The resulting new sampler design keeps the piston and wireline of the Waterloo design but supplements it with an inflatable rubber bladder in the drive shoe (KGS bladder sampler). The bladder takes the place of the steel fingers in the earlier KGS design. Figure 10 shows the design of the bladder sampler drive shoe. The rubber bladder lies deflated behind a plastic sample liner as the core enters the sampler. Near the end of the sampling process (near the end of the 5-foot drive), the plastic liner is retracted resulting in the bladder being placed in direct contact with the sediment. The bladder is then inflated with nitrogen gas (to about 50 psi), closing off the bottom of the sampler. The sampler is then retrieved from the hole with the inflated rubber bladder and the suction exerted by the piston preventing the cored sediments and pore fluids from moving out the bottom of the core barrel. An inflation line made of steel brake line runs from the top end of the drive shoe to the upper end of the core barrel, where it is attached to a conventional air hose that runs to the surface. Figure 11 shows a schematic of the assembled sampler before and after driving and inflation.

## RETRACTION MECHANISM

The retraction mechanism requires some additional description and is shown in Figure 12. When initially loaded with the plastic sample liner, a piston stop is anchored about 4 inches from the top end of the core barrel by two buttons which extend into the walls of the core barrel. The piston stop is turned down to a smaller diameter for the last 3/4 inch to allow the sample liners, which have been fitted with a double wall for the last 3/4 inch, to slide onto the stop. So, in the initial position, the sample liner extends from the front of the drive shoe to the piston stop, covering the rubber bladder. As the sampler is driven forward, the piston moves up the core barrel and eventually hits the piston stop. The piston has been fitted with an extension about 1 1/2 inches in length. This extension will come in contact with a cable that connects the two spring-loaded buttons and retracts the buttons just as the piston hits the piston stop. This action releases the piston stop, which then moves to the end of the core barrel. The double walled lip on the sample liner comes into contact with the piston causing the sample liner to be moved along with the piston and piston stop to the end of the core barrel. This results in the sample liner being retracted about 4 inches, exposing the rubber bladder which is now ready for inflation. Although it may seem complicated, we have had very little trouble with the retraction mechanism. It has only failed to work once or twice due to misadjustment of the piston extension length, and not due to a failure of the mechanism.

## RECOVERY AND DRIVING EQUIPMENT

Earlier workers (Munch and Killey, 1985; Zapico et al., 1987) have used a left-handed sub system to disconnect the drill rods from the sampler prior to wireline recovery. We have designed a quick-disconnect system that releases with a 1/4 turn clockwise when the sample is supported on the bottom of the hole or by the wireline. A picture of the quick-disconnect mechanism is shown in Figure 13. In addition, one needs a means of driving the sampler the desired distance. Other workers have used a hammer mechanism, which can be hydraulically activated or driven by a cat-head, and are typically 100-150 lbs. It is also possible to push the sampler with the rig hydraulics. We have found neither of these options to be satisfactory. Pushing on the sampler in coarse sand usually lifts the rig without significant advancement. When using a cat-head driven hammer system, we have found that we could not get the high frequency of blows necessary for efficient driving. We believe that the frequency of the blows and not the weight of the hammer is the critical factor. For low frequency drivers, the material in contact with the liner wall stops moving between blows and must be remobilized with each blow. For high frequency drivers, the material in contact with the liner wall does not stop moving between blows. Since sliding friction is less than starting friction, the sampler drives more easily. We have found that an 80-100 lb air-driven jack hammer is a very efficient driving mechanism. Figure 13 shows a picture of the device used to attach the jack hammer to the top of the drill rods. Typically, using the high frequency jack hammer driver, we only observe a one-two inch loss that can be attributed to compaction for a five-foot sample. After driving 5 feet, the jack hammer and driving attachment is removed and the sampler is ready to be recovered.

## **SAMPLE RECOVERY**

The first step in sample recovery is to inflate the bladder, thus closing off the end of the sampler. We then pull the sampler back the first 5 feet with the drill rods and the rig hydraulics, because this gives us very precise control. With the sampler resting at the bottom of the flights or with the sampler weight supported by the wireline, we can disconnect the drill rod string and pull the rods in the usual manner. After the drill rods are out of the flights, the sampler is recovered smoothly with the wireline, while keeping tension on and recovering the airline. The sample tube is removed, capped, and labeled with the appropriate information, which includes well identification, sample depth interval, and the vertical direction. The samples are then transported carefully back to the laboratory and stored in the vertical position completely immersed in a container of formation water. They are kept this way until they are prepared for hydraulic conductivity measurements.

Since we would like to measure the vertical profile of hydraulic conductivity, it is very important to continually take good depth measurements. The depth of the open hole inside the auger flights and the height of the auger flights above land surface are measured carefully before each sample is taken. In addition, measurements are made every time after the sampler is recovered to see if sands have heaved into the flights. If one is extremely careful about keeping the head in the flights considerably above the water table, heaving sands can be controlled when tools are moved slowly and deliberately.

## RESULTS

We have cored six of the 23 wells installed at the GEMS site since the spring of 1988. Two of the six wells were drilled in 1988 using the Waterloo sampler design alone. One was done utilizing the KGS finger sampler. The percent recoveries for these wells ranged from 60.3% to 69.7% in the coarse sand and gravel portion of the aquifer. In the summer of 1990, we cored three more holes using the new KGS bladder sampler. In the first of these holes, we were testing two slightly different designs and were experimenting with equipment and procedures. That hole had a 64.8% recovery. The remaining two holes were drilled with the procedures discussed here and had about 86% recovery, discounting one loss due to lack of inflation because of dirt and water in the airline. Note that 90% is the maximum recovery possible with this bladder sampler because 6 inches of the 5 foot sample is lost in the drive shoe, as can be seen from Figure 10. The approximately 4 % loss seen in the last two holes shows up as empty space at the top of the sampler. This loss is due to compaction, premature piston movement, or wall friction preventing material movement into the sampler. Generally, this loss can be held to 2 inches or less. We have cored six holes and recovered about 100 feet of core. These cores have been taken to the laboratory for measurement of hydraulic conductivity, porosity, and particle-size fraction. The cores are analyzed in approximately 6 inch segments. A summary of this work is the subject of a companion paper (H12A-3). Figure 14 shows the porosity data for one of the last two wells where recovery was about 86%. Note the almost complete coverage from 12 to 22.5 meters in approximately 6 inch (15 cm) intervals. Figure 14 is a striking illustration of the heterogeneity present at the site.

## SUMMARY

Site characterization must be addressed if details of contaminant transport are to be described. Ideally, heterogeneities must be characterized at several scales. This work has dealt with core samples with dimensions of a few inches. Many workers have reported difficulty in obtaining relatively undisturbed core samples of unconsolidated coarse sand and gravel. Twenty-three wells have been installed with hollow stem auger techniques at a field site for studying heterogeneity in the Kansas River alluvium. Six of the wells have been cored with various techniques. We have used the Waterloo sampler technique with drilling mud to achieve near 90% recovery in some cases. However, the use of drilling mud is worrisome, so we have developed two new sampler designs to avoid this. The first new design involved movable fingers to close the throat of the sampler. This design works well if the movable sleeve is quickly activated by friction with the sediments, allowing 90% or more recovery. However, the sleeve is often not immediately moved as the sampler is recovered, thereby dramatically decreasing the recovery percentage. Cleaning and maintenance are also intensive with this sampler. A second sampler design, using an inflatable bladder in the drive shoe to close off the sampler throat (KGS bladder sampler), is more promising and we have been able to achieve about 86% recovery out of a possible 90% recovery. The 4% loss is due to compaction, piston movement, or material not moving into the sampler. Six inches of the sample (10%) is always lost due to bladder length and placement. No drilling mud is needed and sample recovery is not a very delicate process. The exciting thing about this sampler design is that it offers almost complete vertical coverage for site characterization in unconsolidated coarse sand and gravel aquifers.

## REFERENCES

- Butler, J.J., Jr., C.D. McElwee and J.M. Healey. 1989. Site characterization in the Kansas River Alluvium. EOS v. 70, no. 15, p. 331.
- Central Mine and Equipment Co. 1987. Catalog of Product Literature. St. Louis, Missouri.
- Hackett, G. 1987. Drilling and Constructing Monitoring Wells with Hollow-stem Augers Part 1: Drilling Considerations. Ground Water Monitoring Review. v. VII, no. 4, pp. 51-62.
- Hess, K.M. and D.R. LeBlanc. 1987. Preliminary Measurements of Aquifer Heterogeneity at a Tracer-Test Site, Cape Cod, Massachusetts. EOS. v. 68, no. 16, p. 299.
- Keely, J.F. and K. Boateng. 1987. Monitoring Well Installation, Purging and Sampling Techniques, Part 1: Conceptualizations. Ground Water, v. 25, no. 3, pp. 300-313.
- Leach, L.E., F.P. Beck, J.T. Wilson, and D.H. Kampbell. 1989. Aseptic Subsurface Sampling Techniques for Hollow-Stem Auger Drilling. NWWA Outdoor Action Cont. pp. 31-50.
- Munch, J.H. and R.W.D. Killey. 1985. Equipment and Methodology for Sampling and Testing Cohesionless Sediments. Ground Water Monitoring Review. v. V, no. 1, pp. 38-42.
- Parsons, P.J. 1960. Movement of Radioactive Wastes through Soil 1: Soil and Ground Water Investigations in Lower Perch Lake Basin. Atomic Energy of Canada Ltd., Report AECL-1038.
- Patterson, R.J., S.K. Frape, L.S. Dykes and R.A. McLeod. 1978. A Coring and Squeezing Technique for the Detailed Study of Subsurface Water Chemistry. Can. Jour. Earth Sci. 15, pp. 162-169.
- Perry, C.A. and R.J. Hart. 1985. Installation of Observation Wells on Hazardous Waste Sites in Kansas Using a Hollow-Stem Auger. Ground Water Monitoring Review, v. V, no.4, pp. 70-73.
- Riggs, C.O. 1983. Soil Sampling in the Vadose Zone. Proceedings of the NWWA/U.S. EPA Conference on Characterization and Monitoring of the Vadose (Unsaturated) Zone, Las Vegas, Nevada, pp. 611-622.
- Zapico, M.M., S. Vales and J.A. Cherry. 1987. A Wireline Piston Core Barrel for Sampling Cohesionless Sand and Gravel Below the Water Table. Ground Water Monitoring Review. v. VII, no. 3, pp. 74-82.
- Zapico, M.M. 1987. Aquifer Evaluation Procedures-Core Acquisition and an Assessment of Slug Tests. M.Sc. Thesis, University of Waterloo.

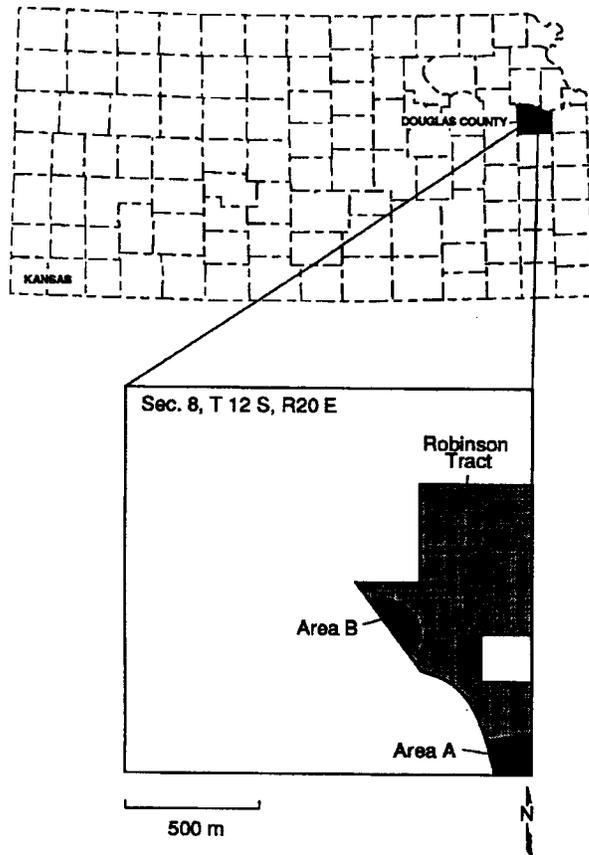
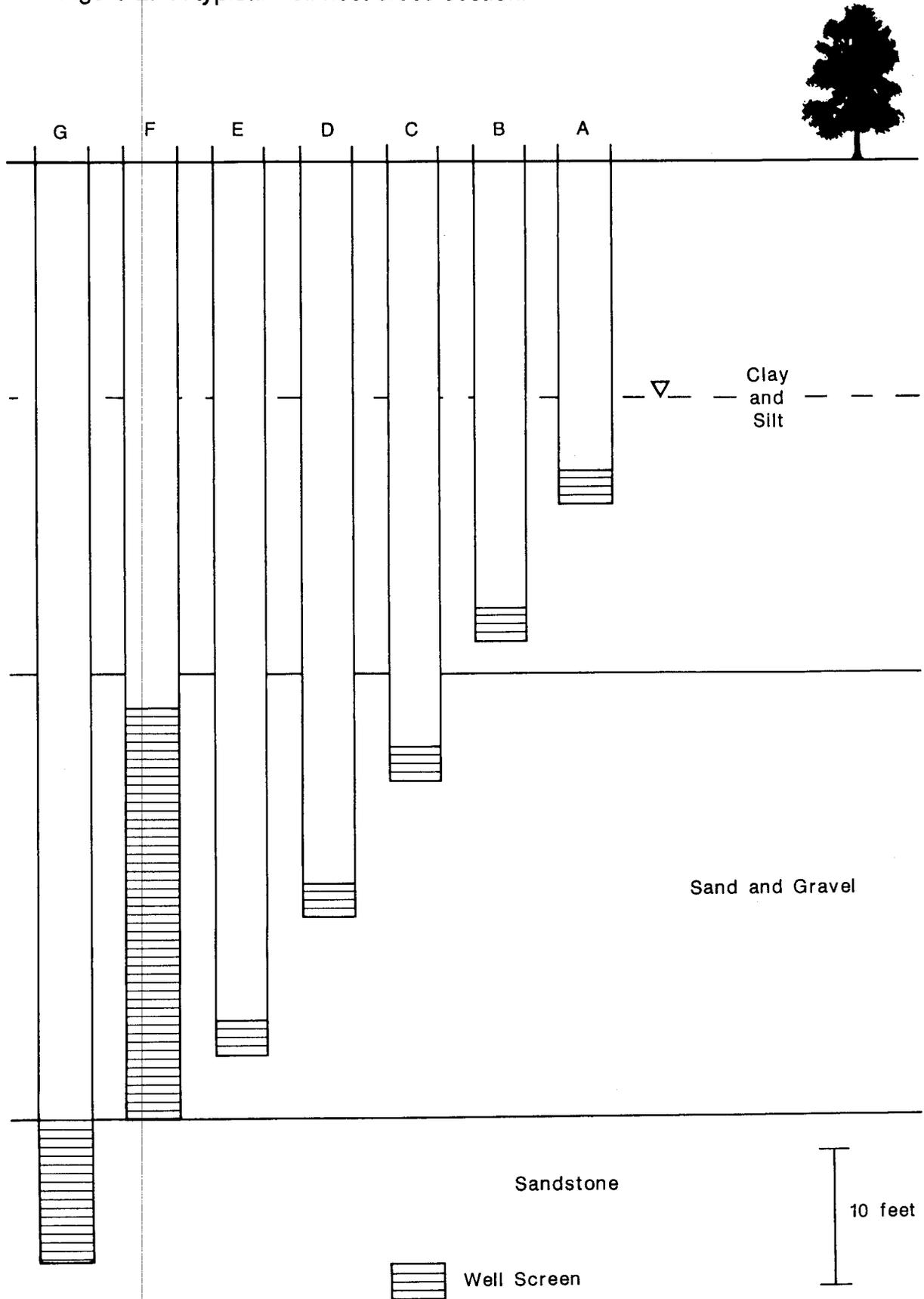


Figure 1. Location of research site.

Figure 2. A typical well nest cross-section.



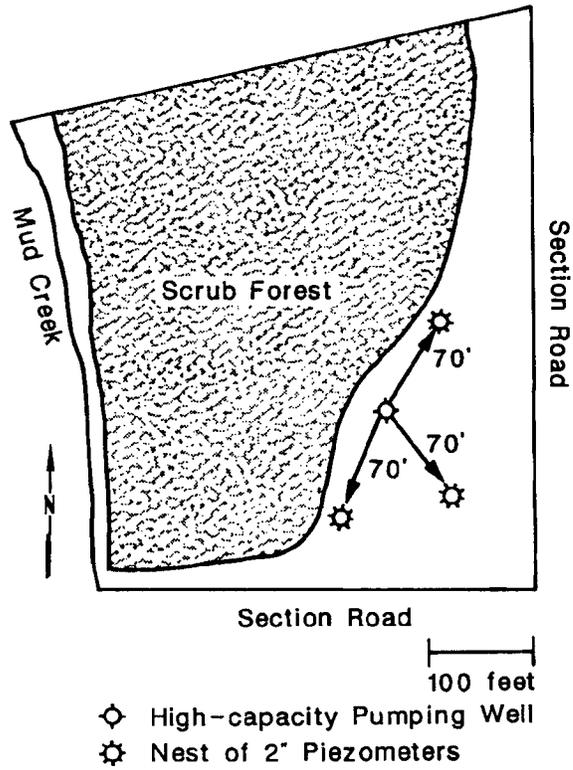
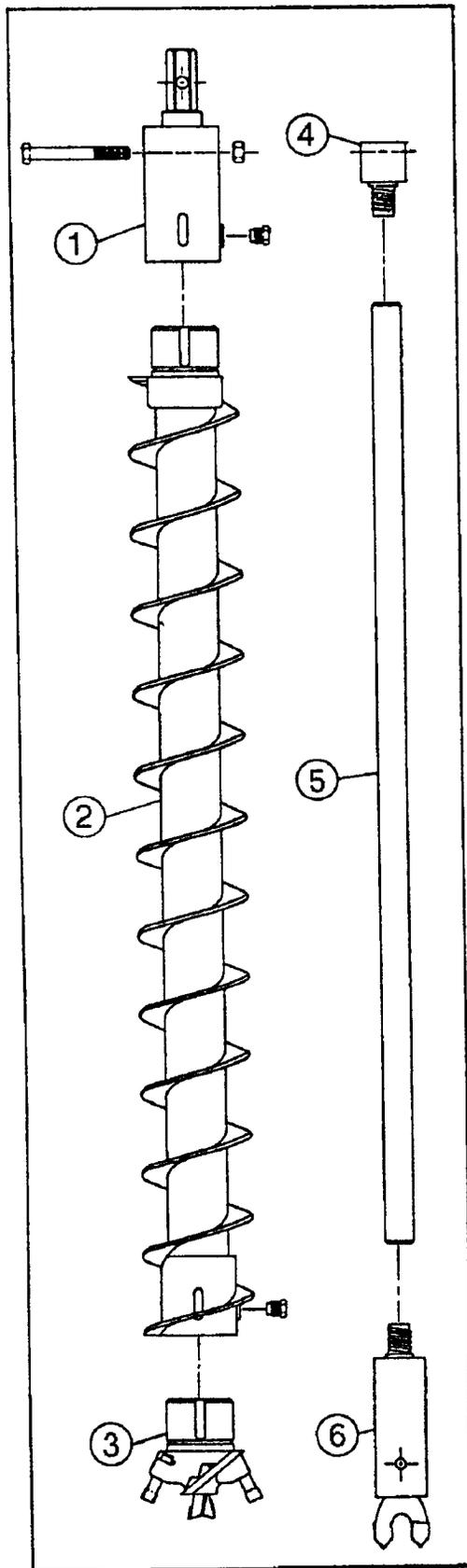
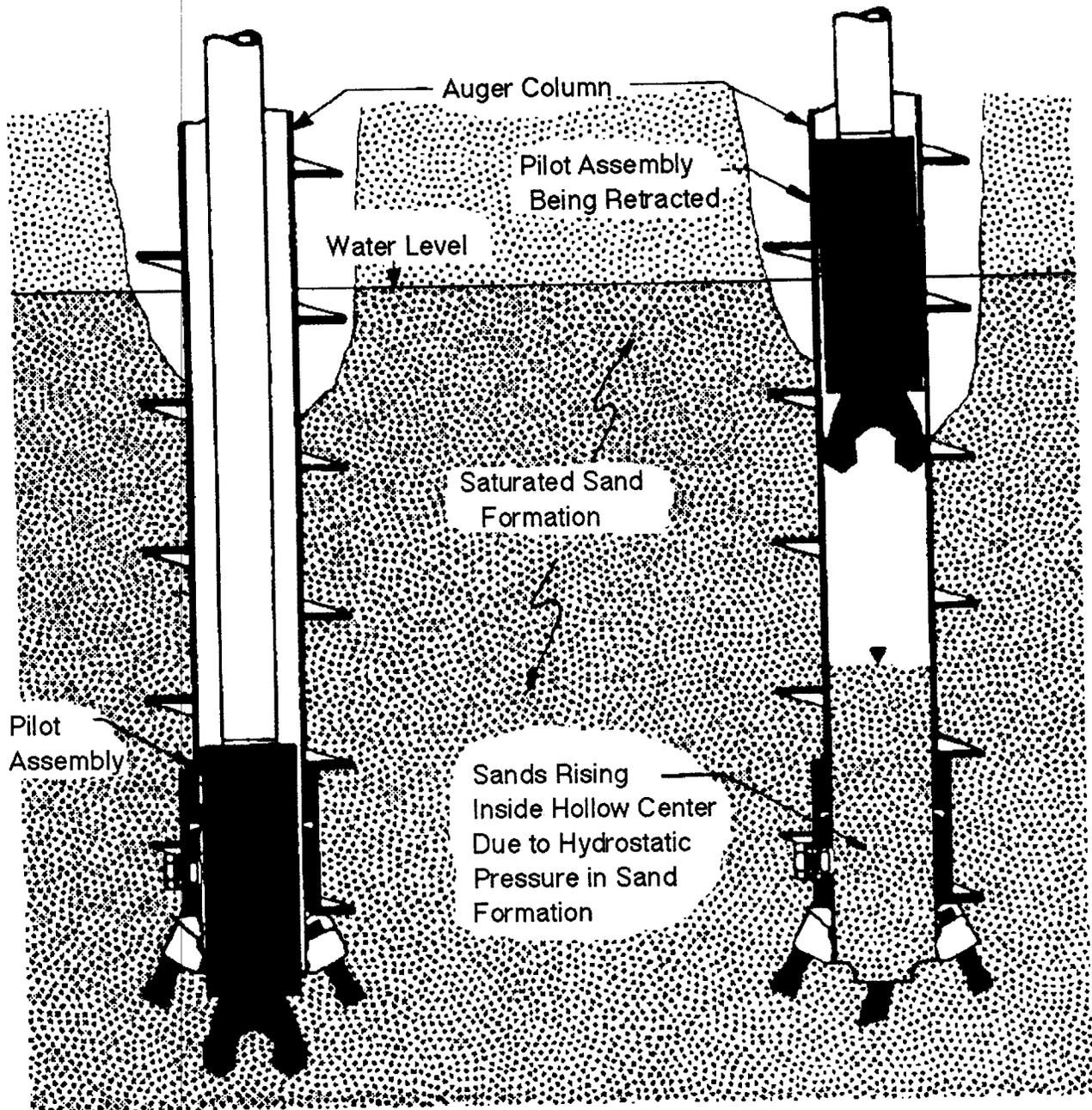


Figure 3. Expanded view of GEMS site.



1. Drive Cap
2. Hollow Stem Auger Section
3. Auger Head
4. Rod to Cap Adapter
5. Drill Rod
6. Pilot Assembly and Center Bit

Figure 4. Typical hollow-stem auger components (after Central Mine Equipment Co.).



a.

b.

Figure 5. Diagram showing heaving sand with hollow-stem auger drilling (after Hackett, 1987).  
 a. Before removing the pilot assembly.  
 b. During removal of the pilot assembly.

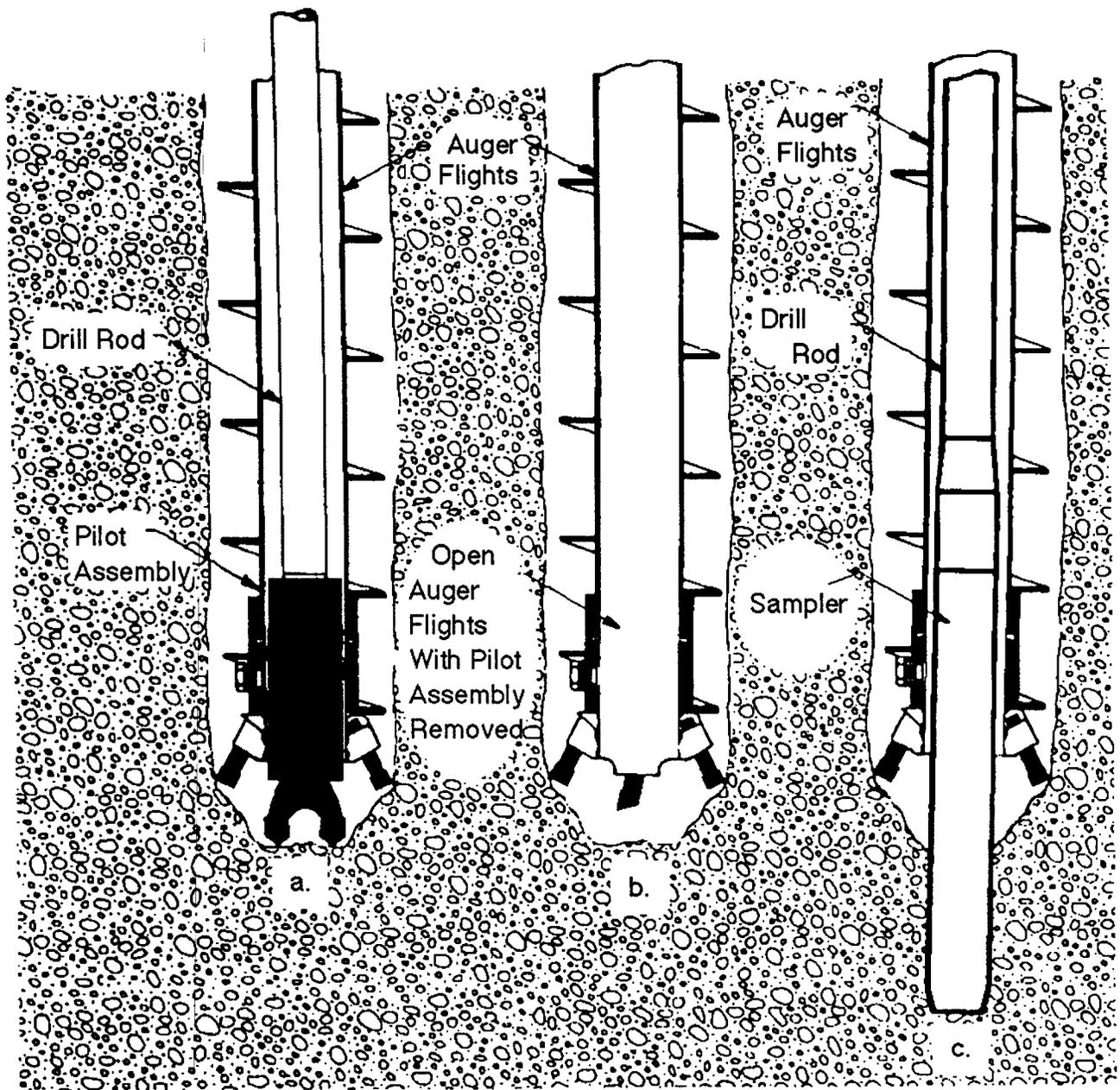


Figure 6. Sequential steps showing borehole advancement with pilot assembly and collection of a formation sample (after Riggs 1983).

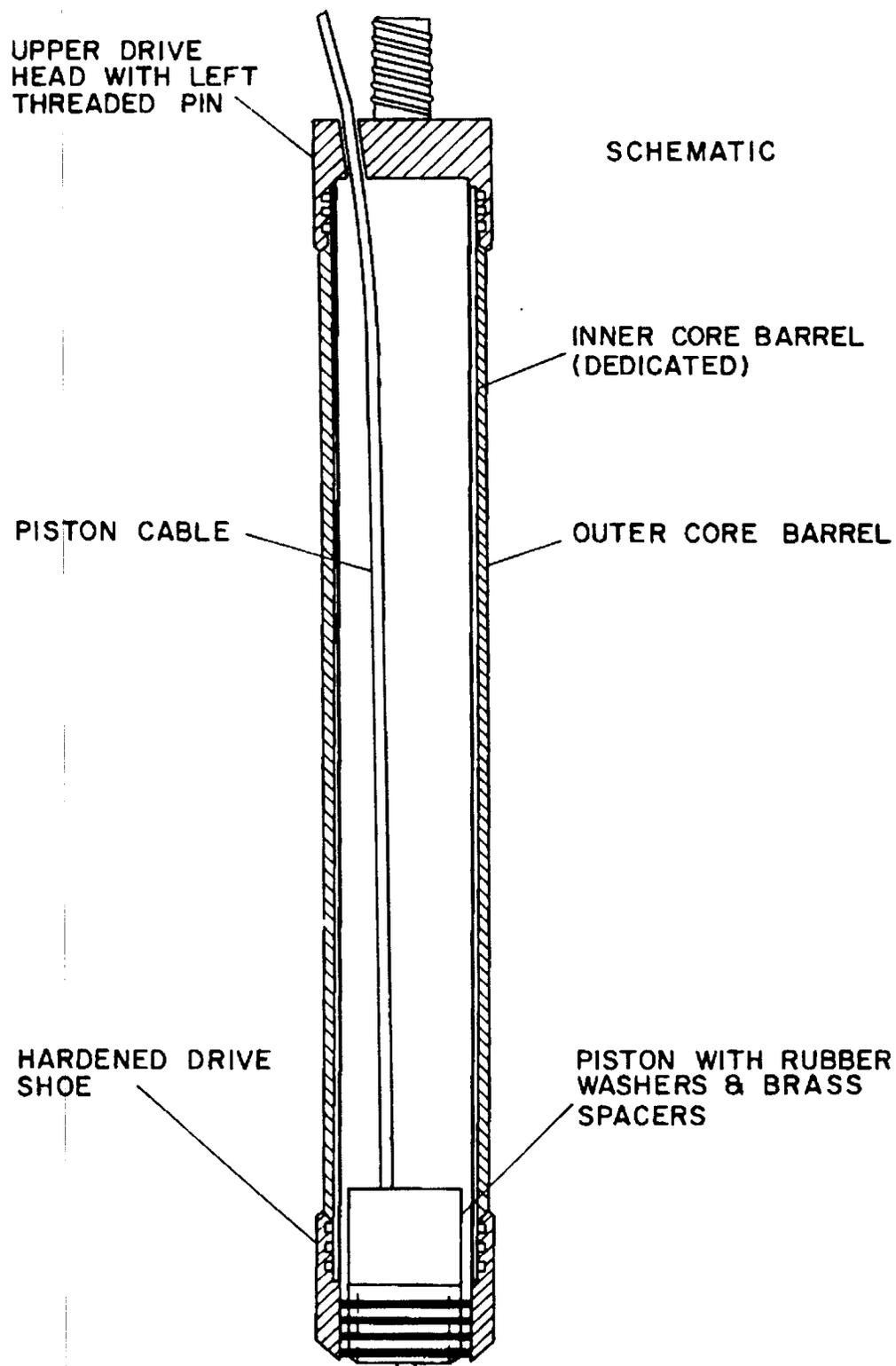


Figure 7. Waterloo piston sampler schematic (after Zapico et al., 1987).

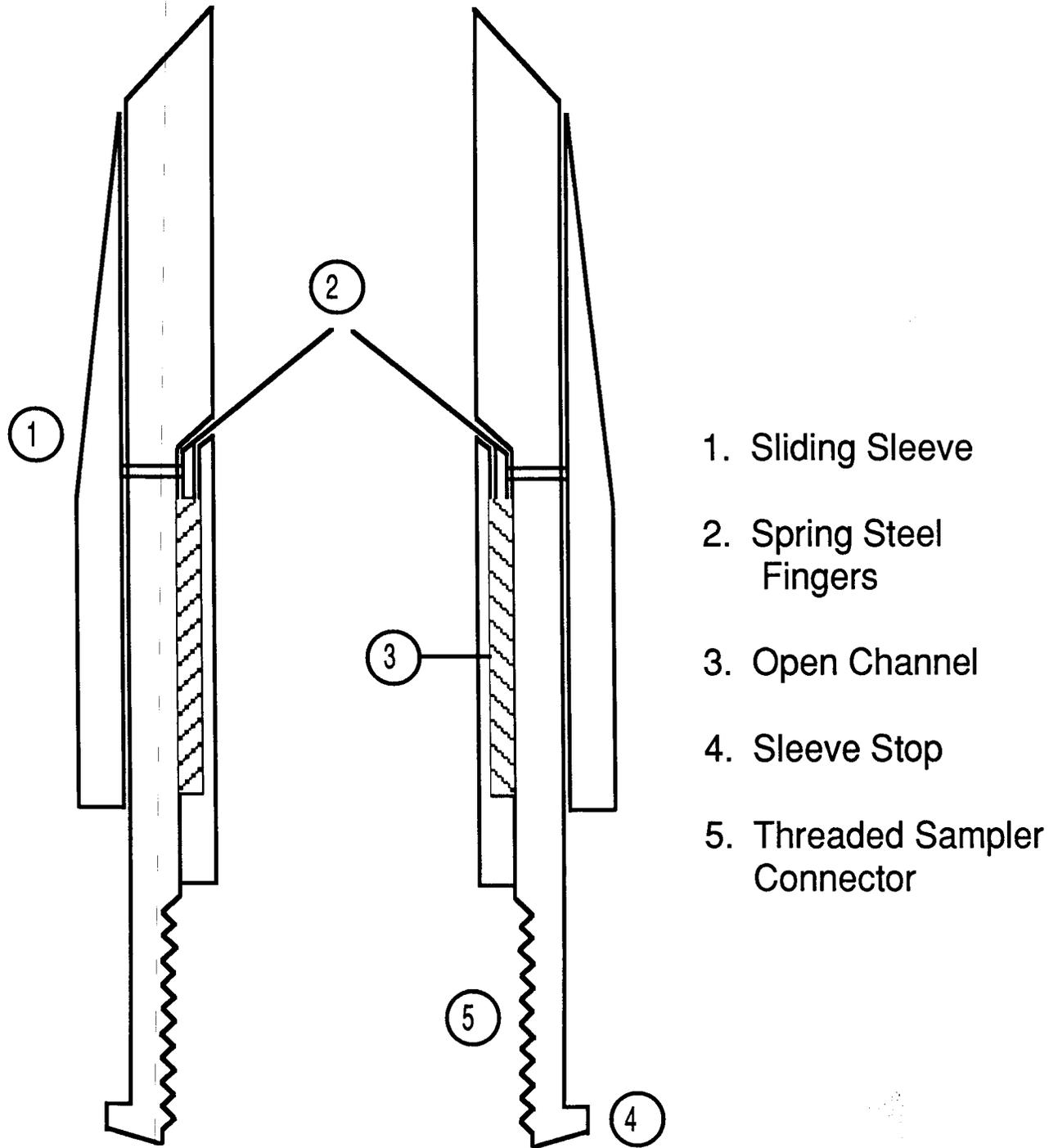
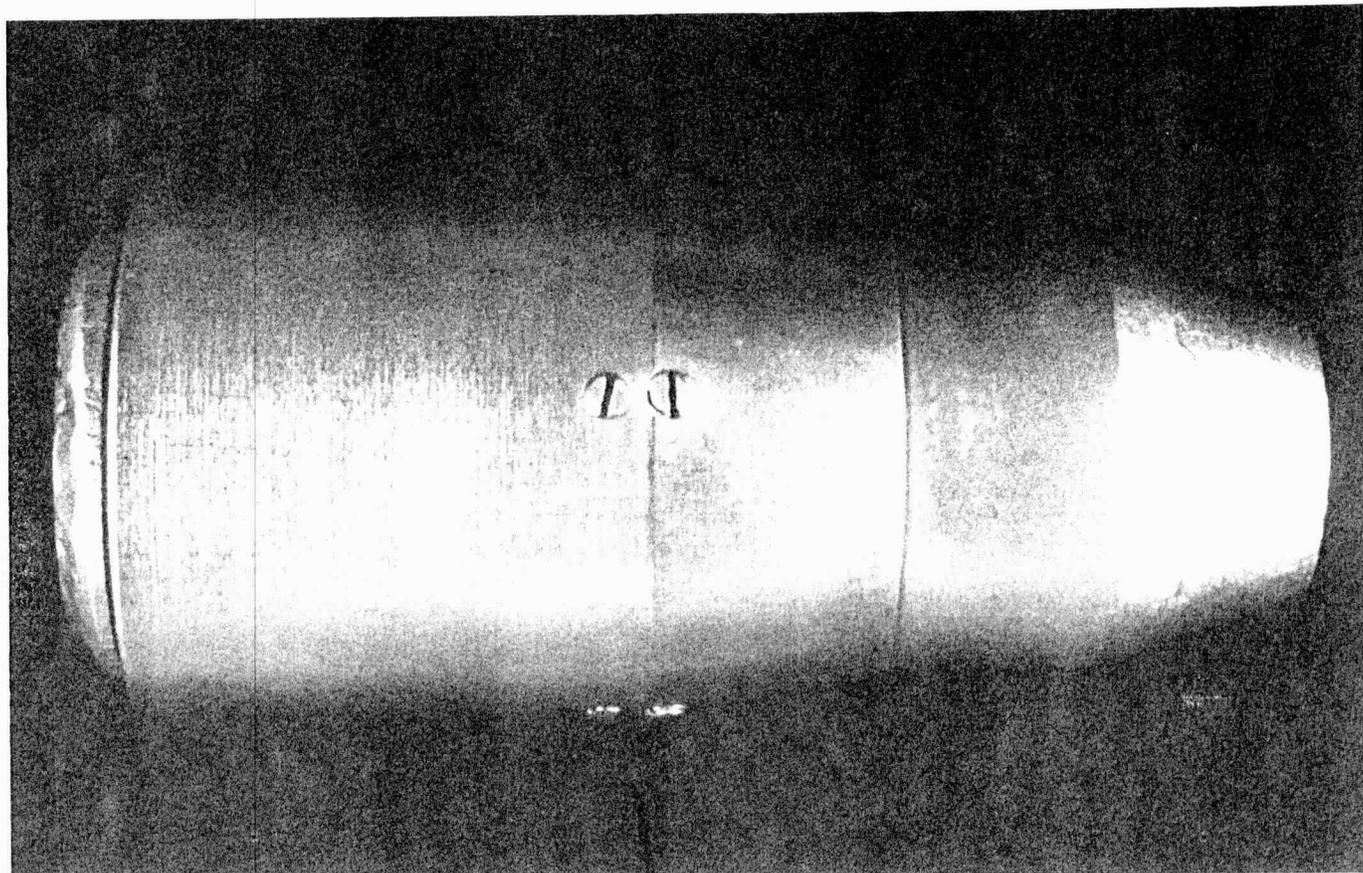
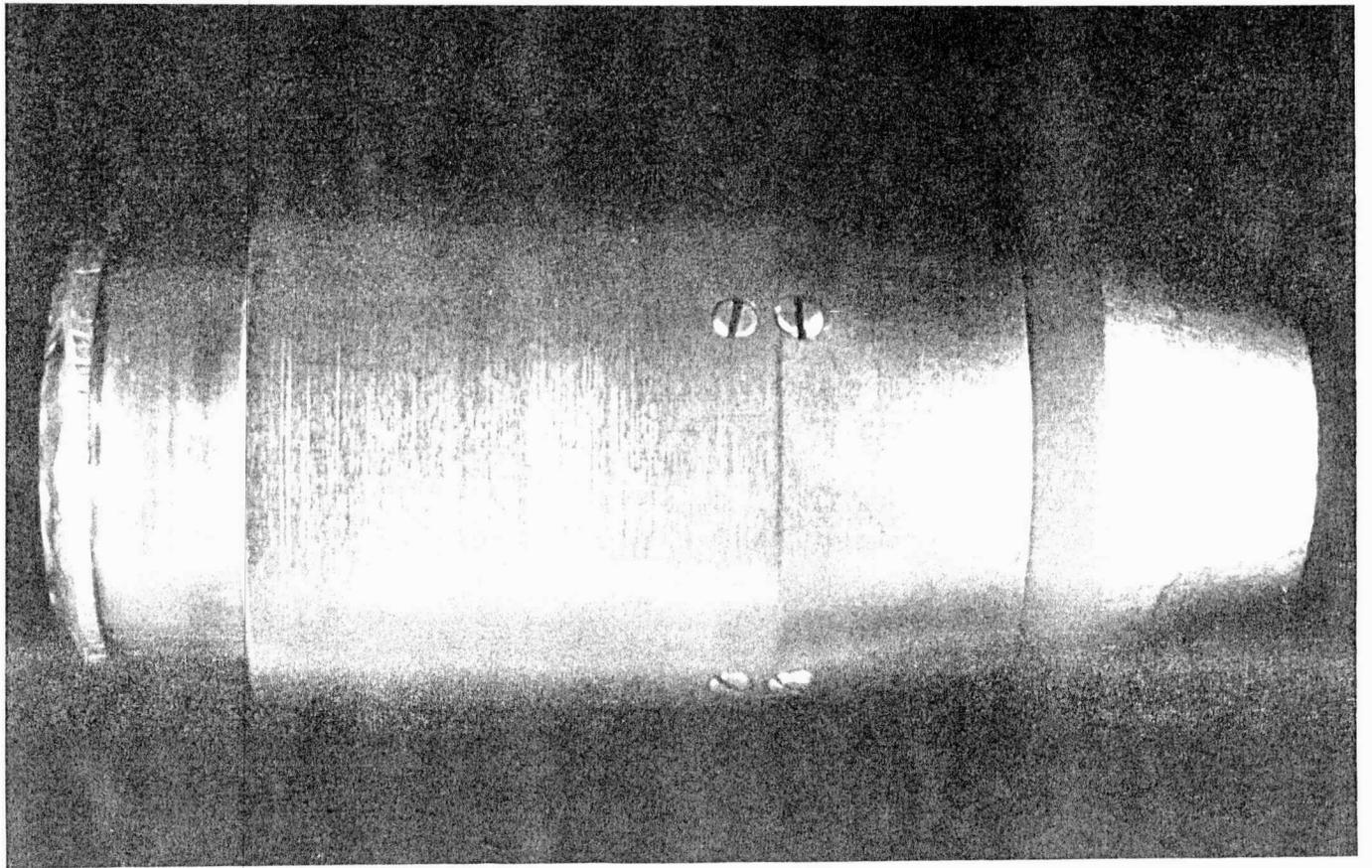
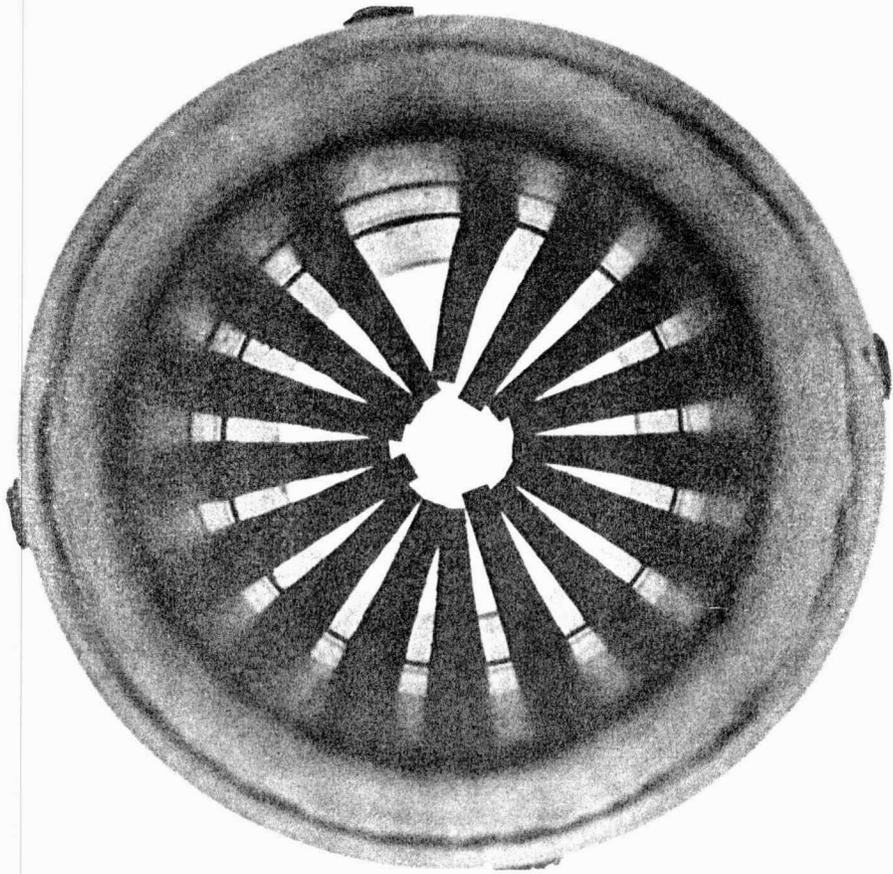


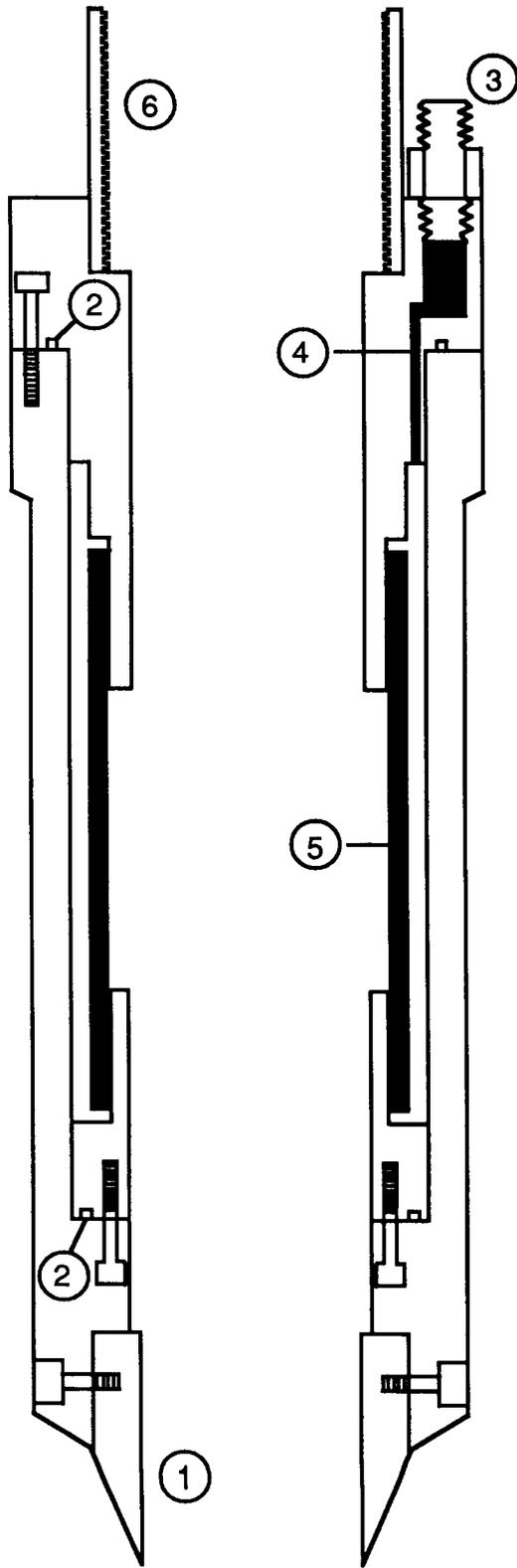
Figure 8. Finger sampler drive shoe.

Figure 9. Photographs of KGS finger sampler.





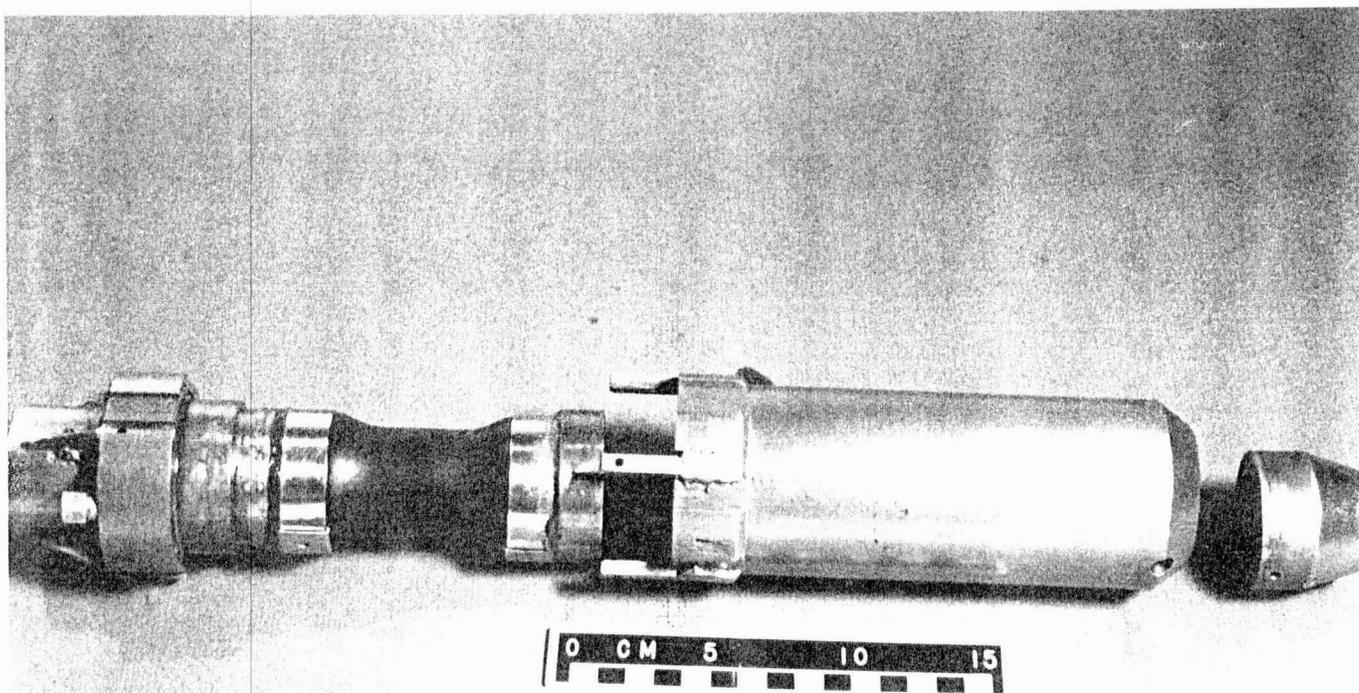




- 1. Hardened Drive Shoe
- 2. O-rings
- 3. Airline Fitting
- 4. Airline Channel
- 5. Inflatable Bladder
- 6. Threaded Sampler Connector

Figure 10a. Bladder sampler drive shoe.

Figure 10b. Photograph of disassembled bladder sampler.



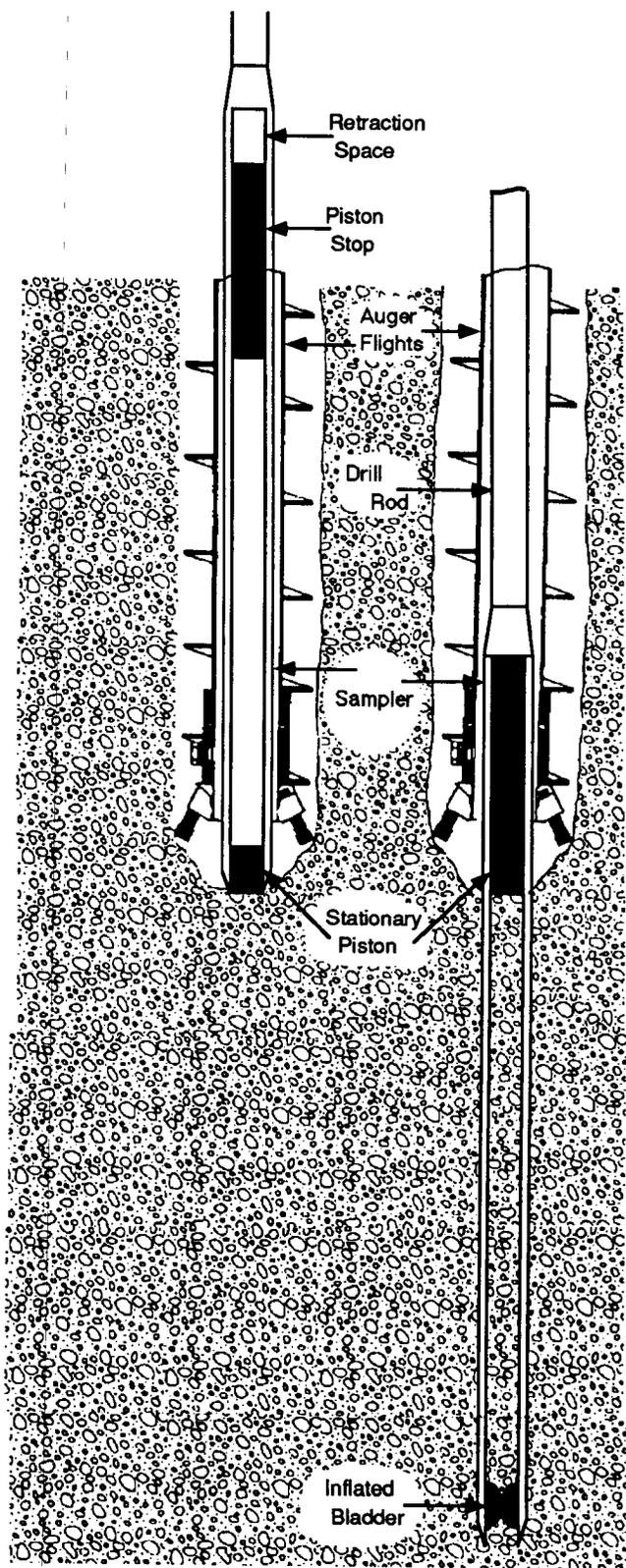
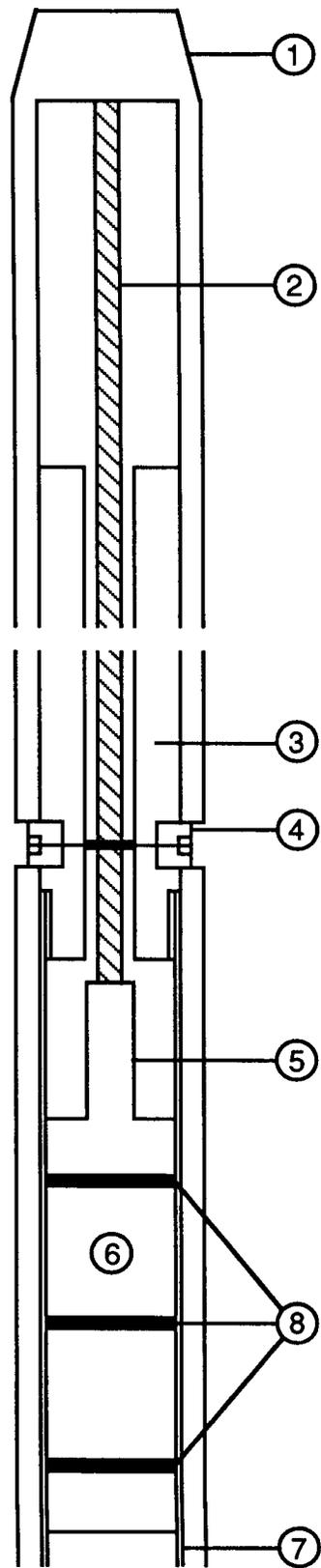


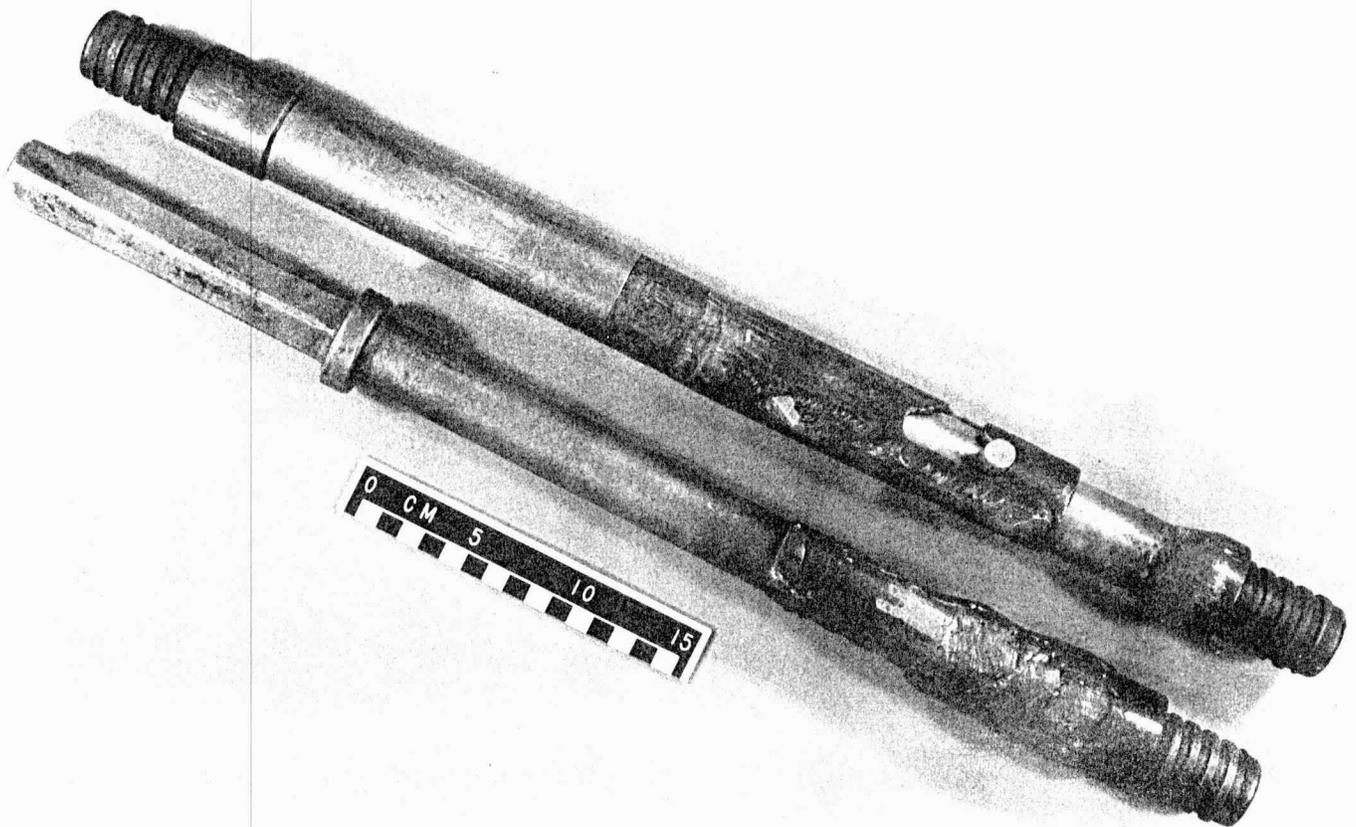
Figure 11. Schematic of sampler before and after driving and inflation.



- 1. Sampler Body
- 2. Piston Cable
- 3. Piston Stop
- 4. Retractable Buttons
- 5. Piston Extension
- 6. Piston
- 7. Sample Liner
- 8. O-rings

Figure 12. Schematic of retraction mechanism.

Figure 13. Photographs of quick-disconnect mechanism and jack hammer driver attachment.



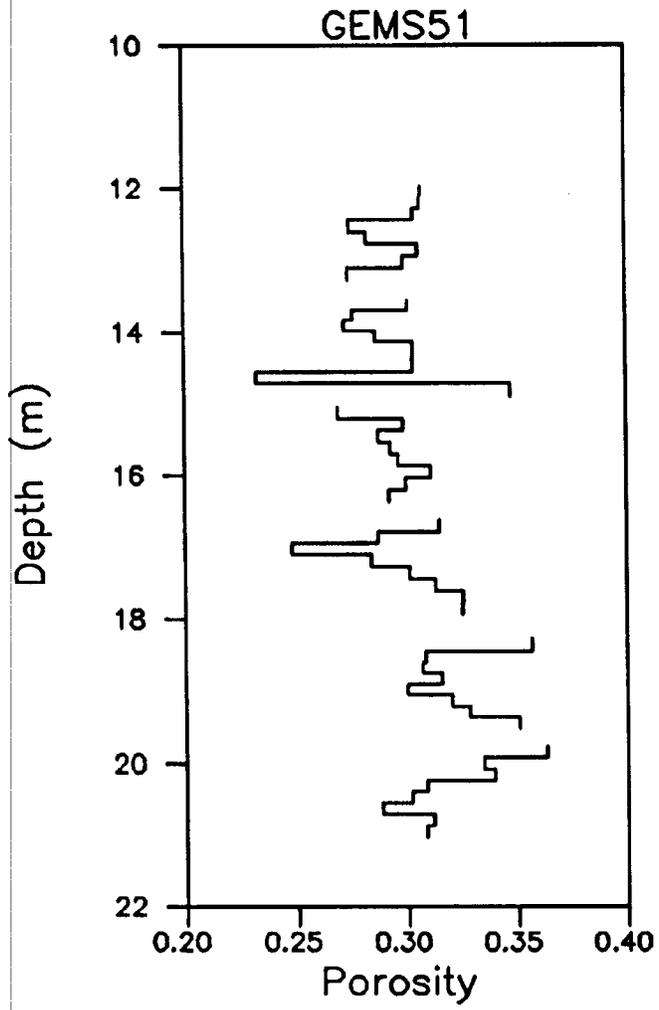


Figure 14. Porosity data for one well at GEMS.