

# IMPROVED X-RADIOGRAPHY OF CYLINDRICAL SEDIMENT CORES

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**ABSTRACT.**—X-rays passing through the center of cylindrical sediment cores during radiography are absorbed to a greater degree than are X-rays passing through the sides of the core. Four methods have been devised to compensate for this effect. (1) The penetrating power of the X-ray beam may be increased. (2) A lead intensifying screen can be used to increase the intensity of X-rays passing through the center of the core. (3) A material similar to that in the core may be packed around the sides of the core. (4) The film density of the central region of the film may be reduced. These methods were quantitatively compared by testing the effects of each method on the exposure and sensitivity of the film. The results of the tests indicated that each method alleviated the problem but to a different degree. Method 3 produced the most even exposure across the film and showed the maximum detail of the internal features of the core.

When radiographs of cylindrical sediment cores are made, X-rays passing through the center of the core tube are absorbed by the sediment to a greater degree than X-rays passing through the sides of the core. The radiograph is unevenly exposed and the gradient of film density (darkness of film) increases from the center toward the sides of a radiograph. A film correctly exposed for the center of the core will be overexposed near the edges, resulting in a loss of detail.

We tested several methods to minimize this problem. Only a tentative solution has been reached because each method introduces factors that adversely affect the film sensitivity or the ability of the film to record detail.

## METHODS

In each of the methods discussed below, a Picker Gemini Model 160 constant potential industrial radiographic machine was used with a 150kV Morris Be-window X-ray tube selected to have a 0.5 mm diameter effective focal spot. The X-ray output from the tube was collimated by a medical-type collimator attached to the tube. The focal-spot to specimen distance was fixed at 100 cm. Kodak AA industrial X-ray film was used exclusively. The film was developed in a Calumet Model 147 nitrogen-burst machine to insure that each film was uniformly processed.

The penetrating power of X-rays may be increased by increasing the potential, or kilovoltage, between the anode and the cathode in the X-ray tube. The "harder" X-rays that are produced at higher kilovoltages are less sensitive to varying thick-

nesses of a cylindrical core and, therefore, reduce the density gradient across the radiograph. Radiographs made from these hard X-rays show less detail of the core because harder X-rays are also less sensitive to differences of density in the object being radiographed.

A second method uses lead intensifying screens to increase the intensity of X-rays passing through the center of the core relative to those passing through the sides. The rays that have passed through the central region are "hard" X-rays of short wave length because the softer rays have been selectively absorbed. Toward the sides of the core, however, more soft rays can penetrate the core because the material is thinner. The intensifying effect increases as wave length decreases (Clark, 1955), so that rays of short wave length penetrating the central region of the core tube are preferentially strengthened. Unfortunately, the ability of the intensifying screens to reduce the film density gradient is somewhat limited.

In the third method, material is packed around the core tube presenting plane parallel surfaces to the incoming X-rays. Thus, X-rays passing through the sides of the core are absorbed to an equal degree as those passing through the center.

Several materials have been used as the absorbing material. Klingebiel *et al* (1967) immersed the cores in liquids of varying densities. The densities of the liquids were matched with the density of the material of the core so that the absorptive characteristics of both materials were the same. The liquids, however, were inconvenient and difficult to handle

during preparation of the core for radiography.

Haase (1967) attacked this problem by placing the cores in molds of plaster or plastic. Plastic was preferred because the plaster contained air bubbles and other imperfections. Baker and Friedman (1970) placed cores in a machined aluminum block. The molds are convenient to handle, but their densities cannot be varied to match the absorptive characteristics of the sediment core. They also may be expensive or difficult to construct.

Bouma (1969) recommended placing the core in loosely packed fine sand. The absorptive effect of the sand could be varied by changing the thickness of the sand pack. A fair match between the absorptive characteristics of the sediment and the sand could thus be obtained. Even though a fine sand is used, however, the graininess of the sand would be shown on the film and would tend to mask detail in fine-grained sediment.

A method which alleviates these problems was devised by Nathan Ayer (1970) in 1967. He designed a plastic box (Fig. 1) containing small glass spheres, called glas-shot® or microshot, as the absorbing material. The box consists of an outer plexiglas shell fitted with an inner

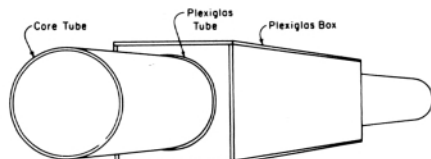


FIGURE 1. Glass bead box designed by Nathan Ayer. The core tube slides inside the plexiglas tube.

plexiglas tube that has an inside diameter only slightly larger than the 4.5-inch (11.4-cm) outside diameter of our core tubes. The microshot ranges from 10 to 53 microns in diameter. (Number MS-XL, Microbeads Division, Cataphate Corp., Jackson, Miss.) The box is convenient because the core can easily be fitted into the plexiglas tube without having to repack the microshot each time a new core is radiographed. The microshot is sufficiently small to prevent masking detail in fine-grained sediments, and the absorptive characteristics of the glass beads are similar to those of many types of unconsolidated sediments. In addition, the absorptive ability can be varied by increasing or decreasing the packing density of the microshot. The glass beads, however, cause some scattering of the X-ray beam that tends to blur the image slightly on the radiograph.

In method 4, the film density of the entire radiograph is decreased until detail can be seen along the edges of the film. This procedure, however, may cause the film density of the central region to become too low, causing the visibility of detail in that area of the radiograph to be reduced.

#### COMPARISON OF METHODS

The relative pros and cons of the four methods may be quantitatively compared by testing the effect of these methods on the density gradient and on the contrast of the film. A synthetic core was constructed for the tests by putting five strips of lead foil on half the width of a plexiglas plate and inserting the plate into

a plastic core tube filled with the same microshot as those in Ayer's box (Fig. 2). A radiograph of the

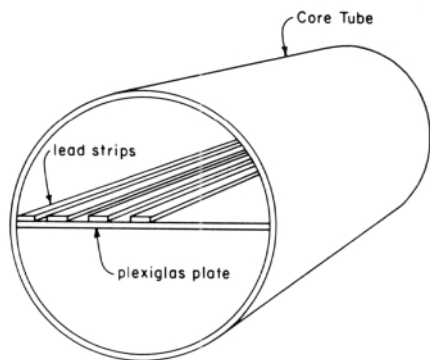


FIGURE 2. Synthetic core used to test the effects of the various methods on the film density gradient and contrast.

core showed the strips of lead as slightly lighter images against a darker background on one side of the radiograph and a gradient of film density progressively increasing from the center to the edge of the other side of the radiograph (fig. 3).

The film density of the images of the five lead strips and of the corresponding areas on the opposite side

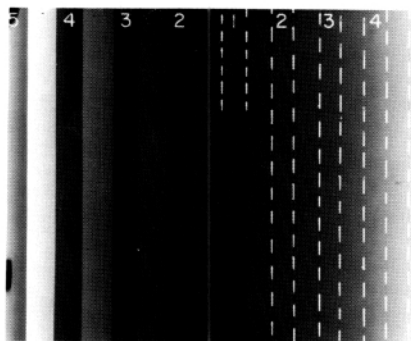


FIGURE 3. Typical test radiograph print. The darker areas represent the lead strips and areas enclosed by the dashed lines are the counterpart areas to the images of the lead strips.

of the film were measured. To compute the film contrast, the arithmetic difference was determined between the film density of the image of a lead strip and the film density of its counterpart area on the opposite side of the film. The film contrast also had a gradient from the center to the edge of the radiograph.

Three sets of graphs were prepared to show the effects of the various methods on the density gradient and the film contrast. The first set (Fig. 4) compares the film density gradient for each of the first three methods and for three different kilovoltages. The graphs are plotted with film den-

sity as a function of distance from the center line of the radiograph of the core tube. The initial film density (film density of the center line of the radiograph) was 2.00 in all cases. The angle of the slope of any of the plotted curves bears an inverse relation to the film density gradient.

The second set of graphs (Fig. 5) are plots of the film contrast gradient for the first three methods and for three different kilovoltages. The contrast is plotted as a function of distance from the center line of the radiograph with an initial film density of 2.00. The angle of slope of

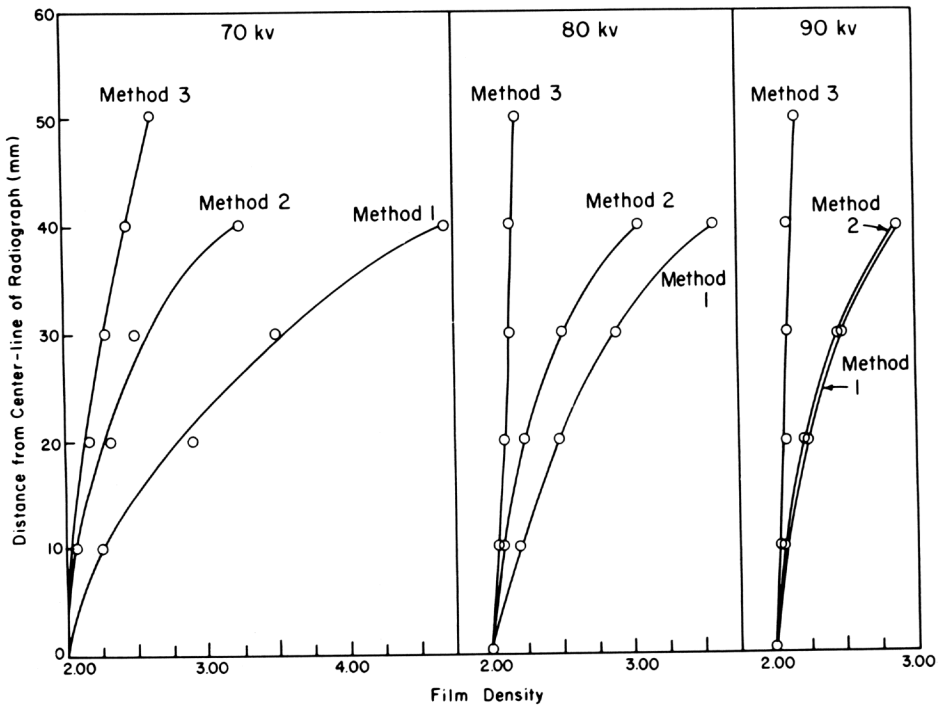


FIGURE 4. Plot of the film density as a function of distance from the center line of the radiograph for methods 1, 2, and 3 with three different kilovoltages. No film densities could be measured beyond 40 mm from the center line of the film for methods 1 and 2 owing to extreme blackening of the film.

any of the curves bears an inverse relation to the film contrast gradient.

The third set of graphs (Fig. 6) was prepared from data taken from radiographs in which the initial film density was set at 1.00, 1.50, and 2.00, while the kilovoltage was held constant at 70 kV. These graphs were prepared to show the effects of method four (decreasing the initial film density) on the density gradient and the contrast gradient.

Figures 4 and 5 show that the microshot box, method 3, is the best mechanism for reducing the film density gradient. This method, however, also has the most detrimental effect on the film contrast. In all

graphs, the microshot box method showed the lowest contrast at the center line of the radiograph and also the slowest rate of increase from the center to the edge of the radiograph. Use of the lead intensifying screen in method 2 decreased the film density gradient slightly, but it was not as harmful to the contrast as method 3. Increasing the kilovoltage decreased the density gradient considerably but also adversely affected the contrast. The film densities at the edges of the radiographs made using methods 1 and 2 were too high to be measured, i.e., no light penetrated these areas when a high-intensity X-ray illuminator was used.

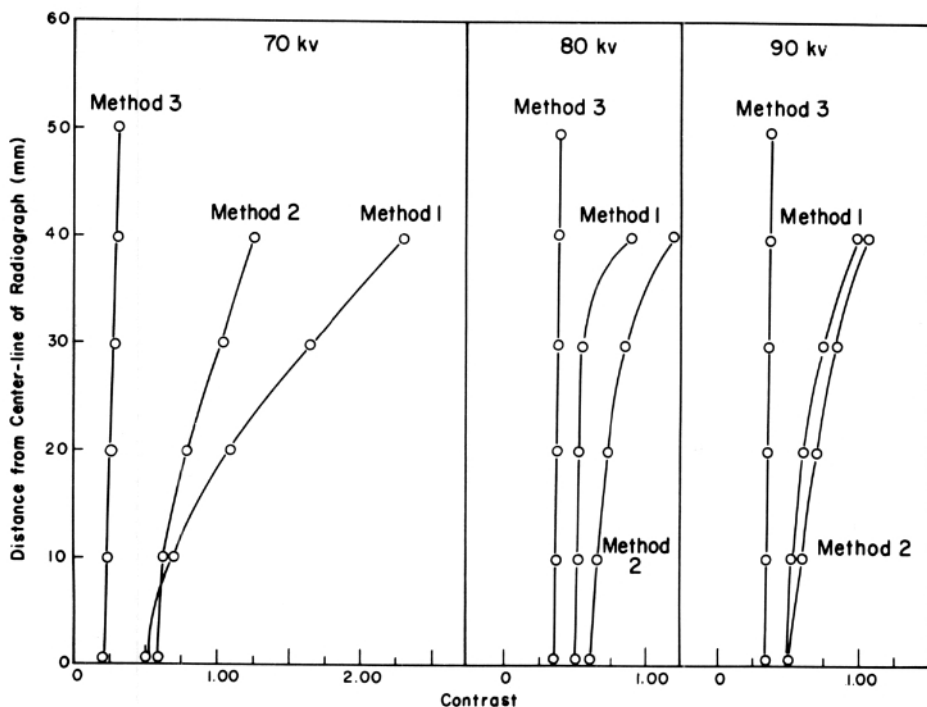


FIGURE 5. Plot of the film contrast as a function of distance from the center line of the film for methods 1, 2, and 3 using three different kilovoltages. No film densities could be measured beyond 40 mm from the center line for methods 1 and 2 because of extreme blackening of the film.

Figure 6 shows that with an initial film density of 1.00 the density gradient was the lowest and the contrast of the center portion of the radiograph was so low that the contrast gradient became negative. Increasing the film density to 1.50 increased the contrast but also greatly increased the film density gradient. An initial film density of 2.00 showed the best contrast and also the most extreme film density. In all tests, the edges of the radiograph were completely blackened, and it was impossible to measure the film density with a high-intensity illuminator.

Although the evidence of the graphs seems inconclusive, it should

be pointed out that an extreme film density gradient is much more adverse to radiographic sensitivity than a steep contrast gradient is beneficial. A satisfactory compromise is found by decreasing the density gradient and accepting the slightly adverse effects produced on the contrast of the film.

Methods 1, 2, and 4 left 10 to 15 mm of a radiograph completely opaque when viewed on the available illuminator. Method 3 was the only method tested that produced acceptable film densities across the entire radiograph and showed the maximum detail of internal features on X-radiographs (Fig. 7).

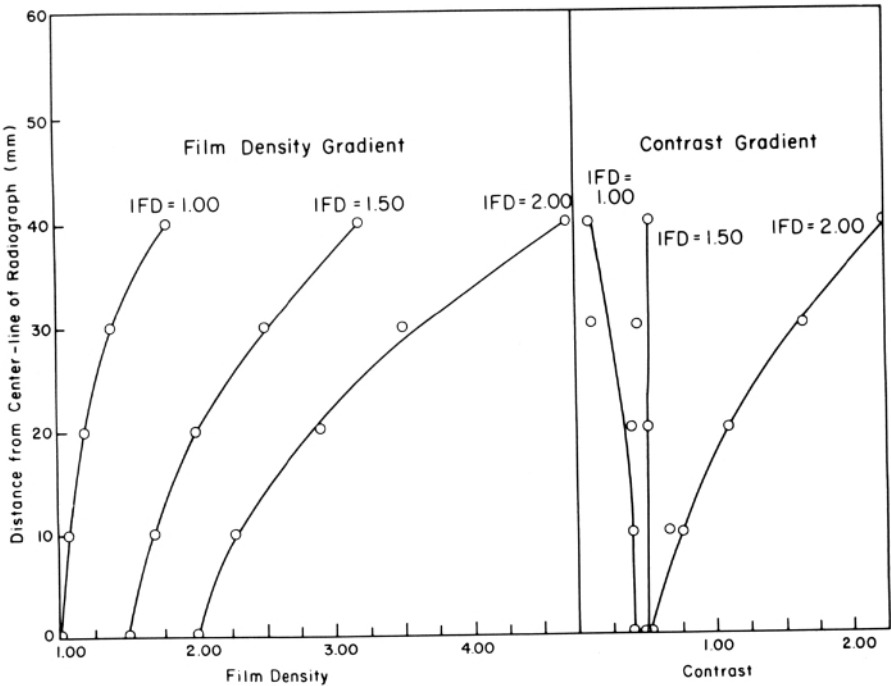


FIGURE 6. Plot of the film density and the contrast as a function of the distance from the center line of the film for three initial film densities (IFD), 1.00, 1.50 and 2.00. Blackening of the film beyond 40 mm from the center line produced film densities too high to be measured.

## DISCUSSION

A film density of about two is considered optimum in industrial radiography. Lower film densities lack detail, and higher densities are difficult to view with conventional high-intensity viewers. A film density of two is opaque to the eye when viewed without the use of a high-intensity illuminator. While optimum detail of the film negative is possible using the viewer, we have found that it is difficult to obtain satisfactory positive prints. The dynamic range of most photographic papers evidently is insufficient to satisfactorily record the detail present in the negative. Very long exposure times also were necessary to obtain suitable prints from the dense negatives. Small differences in film density caused by the geometry of the radiographic box used in method 3, in particular, resulted in unsatisfactory prints made by conventional photographic pro-

cedures. A number of methods were tried to solve this problem. The most satisfactory results were obtained using the Mark II Log-Electronic contact printer.

## ACKNOWLEDGMENTS

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FIGURE 7. X-radiograph print using the microbead box of a sediment core within a 11-cm-diameter core barrel of Delrin plastic. A gastropod shell is the dominant feature in the core. Smaller features probably are clam shells.

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