Universal Stages For Foraminifera

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Introduction

Free-hand manipulation of Foraminifera-sized objects (most are between 0.1 mm and 1 mm) is easy at low magnification. Under a stereo microscope, soften the glue with a moist fine-pointed brush; push the object into the position you want; and hold it until the glue dries (Figure 1A). As magnification increases, free-hand manipulation becomes a challenge. Above 100 magnifications, if you are careless, your picking brush can come crashing into the field of view, destroying all in its path.

"But...", you say. "Just orient the specimen at low magnification, then zoom in for the close view." Sometimes that works, but sometimes you need the close-in view to fine-tune alignment. Photography is a related concern. It can be difficult to align a specimen exactly as you wish, and then, if using a Greenough-style stereo scope, your alignment is messed up by the inclined optical path. Lumpy specimens (including most Foraminifera) often won't lie in the orientation you prefer. Finally, some specimens are too fragile for much direct handling. The solution to all these problems is to temporarily place your specimen on an **object rotator** where you can smoothly and continuously vary orientation for detailed visual examination and photography.

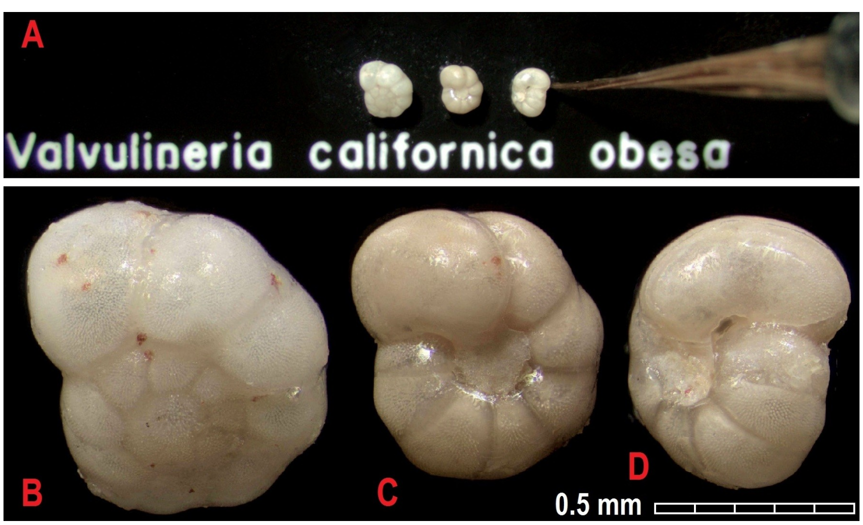


Figure 1. *Free-hand placement of microfossils, showing some of the problems to overcome when orienting specimens for photography.* ***A:*** *Overview showing three specimens being placed on a dry mount micropaleo slide using a fine-pointed brush. The species name is part of the slide background. The result is good for visual examination, but is not quite perfect for photography. There are two main problems: Specimen* ***B*** *tilts due to resting on the bulbous final chamber; and all three specimens appear to lean because of the inclined view of the stereo microscope. "Valv cal obesa" is a Miocene California species, about 14 million years old. Specimen* ***C*** *shows the umbilical calcite flap, or "valve", that gives the genus its name.* ***B****,* ***C****, and* ***D*** *are computer composites of 52, 48, and 43 focus levels made with CombineZP image stacking software. Zoom in to see detail.*

Object Rotators

Devices to mechanically adjust specimen orientation have various designs, but there are three main types:

- **Single-Axis Stages** include 18th and 19th Century stage forceps, modern day gem clamps, and the spindle stages used by crystallographers. Brian Darnton (2010), in a ***Micscape*** article, described a single-axis rotator for orienting Foraminifera.
- **Ball-And-Socket Stages** are the cup stages, also called tilt stages. They tend to be used for large specimens that need limited tilting. They are good for petri dishes, microchip wafers, coins, and arrowheads. Ian MacGregor (2007) (article), (2008) (article), and (2010) (article) described several cup stages in ***Micscape***.
- **Multi-Axis Stages**, which are the subject of this article, are the universal stages: they can position an object in any orientation. They include the four stages described in this article, insect stages for rotating pinned specimens, and the bullet chucks of forensic microscopes. The high end of this category is the crystallographic universal stage. The common feature of multi-axis stages is that the specimen is located where the axes of rotation intersect, so it remains centered and in focus as it rotates (Figure 2).

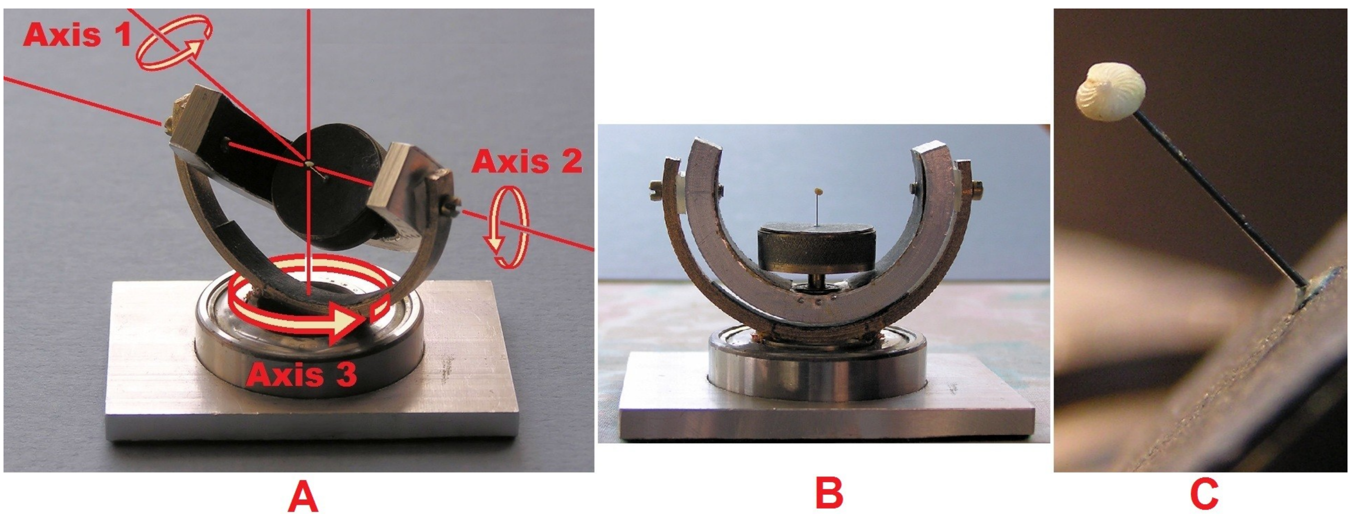
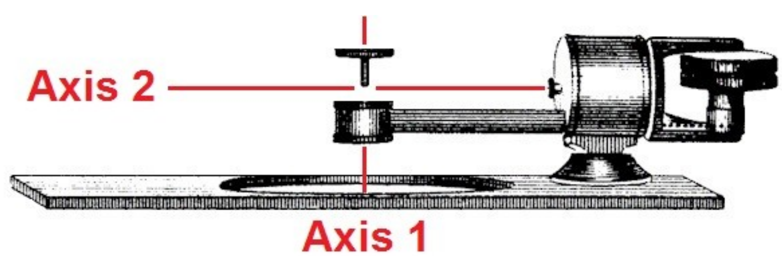


Figure 2. *A three-axis universal stage made by the author. The base plate is 2.75 inches x 2 inches (70mm x 50mm).* ***A:*** *Axes of rotation. The specimen (a Pleistocene Elphidium crispum) can be rotated to display any side except the surface by which it is glued. It remains approximately centered and approximately in focus as it rotates.* ***B:*** *Side view showing the ball bearing mounts for Axes 1 and 3.* ***C:*** *Closeup of "A"; this is a lateral view at right angles to what the microscope sees; the mounting pin coincides with Axis 1. The specimen is temporarily attached to the mounting pin with gum tragacath.*

The Inspiration: Two Classic Designs For Multi-Axis Stages

The **Beck Opaque Disk-Revolver** (Figure 3) is the granddaddy of this type of stage. It was first produced in the1860s. Good photographs of this instrument with its storage case and accessories are shown on the Antique-Microscopes website (link), although it is shown with the horizontal arm rotated upside down in a non-working position. Richard Beck (1865, pg 27-29, and Plates IX, X, XXVI) describes the instrument he designed, and points out that 5 of the 6 sides of a cube can be examined without remounting the specimen.

Figure 3. *Beck Opaque Disk-Revolver circa 1860s to 1890s. This two-axis stage relies upon the microscope to provide the third axis of rotation. Illustration modified from Beck (1865).*



William Carpenter (1868, pg 128, Section 95) had this praise for the Beck Opaque Disk-Revolver:

> *For the examination of Objects which cannot be conveniently held in the Stage-forceps, but which can be temporarily or permanently attached to Disks, no means is comparable to the Disk-Holder of Mr. R. Beck in regard to the facility it affords for presenting them in every variety of position.*
>
> *... To the value of this little piece of apparatus the Author can bear the strongest testimony from his own experience, having found his study of the Foraminifera greatly facilitated by it.*

Specimens were placed on a disk, and the disk was inserted into the Disk-Revolver with special forceps. Notice in Figure 3 that the disk, when inserted, has its upper surface at the intersection of the axes of rotation, so specimens remain centered in the field of view and in focus as they rotate. If the microscope has a rotating stage, the third axis of rotation allows the specimen to be completely aligned.

Beck intended the disk mounts to be permanent, and provided elaborate cases for their storage. There would be problems following that plan: specimens are exposed and at risk, there is no space for labels, disks are easily mixed up, and a great many disks are required. It is not practical to leave specimens on the disks. As Carpenter hinted, the better plan is to store specimens in slides and place them temporarily on a disk for observation.

Disks have some drawbacks. When a specimen is photographed on a disk, distracting background ends up in the picture. The disk limits the tilt to 90 degrees, so there is no "peeking under the edge". Suspending the object on the tip of a needle, as in Figure 2, answers both concerns.

The **Zeiss "Device For Examination Of Jewel Bearings"** (Gerät zum Prüfen von Lagersteinen), shown in Figure 4, is nearly 100 years younger than the Beck Opaque Disk-Revolver, but is built along similar lines. It was developed just before or during World War II; it went into commercial production after the war, with nearly identical versions offered by West German Zeiss and East German Zeiss. The stage illustrated in Figure 4 was purchased on eBay a few years ago. It was manufactured in 1961 or 1962 by East German VEB Zeiss Jena.

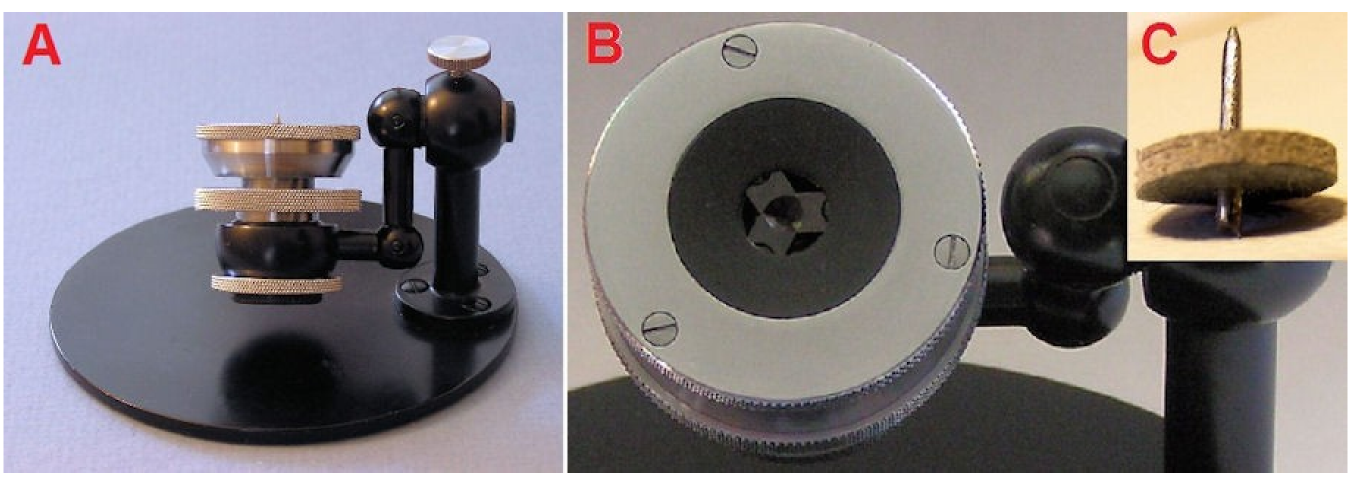


Figure 4. *Zeiss "Device For Examination Of Jewel Bearings" circa 1940s to about 1975; a two-axis stage for use on stereo microscopes.* ***A:*** *Overview. The circular base replaces the stage plate of the Zeiss microscopes for which it was designed.* ***B:*** *Closeup view of the three-jaw, spring-activated chuck.* ***C:*** *Accessory to hold Foraminifera. The bottom of the pin is held in the chuck; the cardboard disk covers chuck openings and prevents loose specimens from falling in; the specimen is glued to the upper end of the pin.*

The Zeiss rotator is a precision instrument, but is intended for objects larger than Foraminifera. The specimen chuck (Figure 4B) opens when the top is pushed down; it holds objects from 1 mm to 4 mm diameter. I added a pin on a disk (Figure 4C) as a means of attaching Foraminifera. When chuck height is adjusted so the tip of the pin is at the intersection of the rotation axes, the apparatus is configured as a universal stage. Some drawbacks: the large chuck limits tilting and can cast shadows on the specimen; the chuck is usually visible as unwanted background in photographs. Zeiss's idea about the use of this device was: “Especially used in the watch-and-clock-making industry for checking jewel bearings” (1962 VEB Zeiss Jena SM XX catalog). This is a great little stage, with many more uses than the one mentioned, but it is rare. My guess is that the two Zeiss companies produced more catalog illustrations of this specialty item than they did actual stages.

Large Three-Axis Homemade Stage

Now we move on to making our own stages, keeping in mind the strengths and weaknesses of the two designs just considered. The stage shown in Figure 2 is a large three-axis stage that sits on the stage plate of a stereoscopic microscope; it allows full adjustment of orientation with great precision. To see the surface by which the specimen is glued (the 6th side in Beck's cube analogy), moisten the glue and roll the specimen.

The stage was built from parts on hand. The design should be clear from an examination of Figure 2. The central wheel was turned from brass, fitted into the small bearing, and the bearing was crimped into the inner cradle with a center punch. Holes for the machine screws that join the cradle were aligned to fall along a single axis. The cradle assembly was epoxied to the inner race of the large ball bearing, and it was centered under the stereo microscope before the epoxy hardened. Likewise, the insect mounting pin was epoxied into its hole in the central wheel, and the tip was brought into the axes of rotation under the stereo microscope before the epoxy hardened. Mat black paper strips, which are less reflective than paint, were attached to reduce glare. This stage is convenient and works well for detailed visual study and photography under a stereo microscope. At 160 magnifications, a push of the bearing-mounted wheel allows it to turn on its own inertia, and the specimen spins in place without leaving the field or losing focus. To paraphrase William Carpenter, my study of the Foraminifera has been greatly facilitated by it.

Small Two-Axis Homemade Stage

The three-axis universal stage shown in Figure 2 is too bulky for a standard microscope. Additionally, you need machinist's tools to construct it. Figure 5 shows a second smaller stage design that is easier to build, and that can be used on both standard microscopes and stereo microscopes.

Figure 5. *Small 2-axis stage built on a 1 inch x 3 inch glass microscope slide. The microscope's rotating stage provides the third axis of rotation. This stage works equally well on a stereo microscope, where it can be rotated by hand for the third axis.*

Figure 6. *Plan for the small 2-axis stage. **A:** insect pin. **B:** Adjustment wheel. I used an aluminum SEM sample plug. **C:** small ball bearing. **D:** Inner cradle, cut from .02" (.5 mm) soft steel. Large hole fits the bearing; small holes fit the screws. **E:** Outer cradle, cut from the same material as D. Small holes fit the screws. **F:** Base. I used a glass microscope slide; wood, metal, or plastic also work. **G:** Spacer, 1/8" thick, drilled to take screws. I used polyethylene. **H:** Small machine screws, 0.12 inch (3 mm) diameter, and 0.33 inch (8 mm) long.*

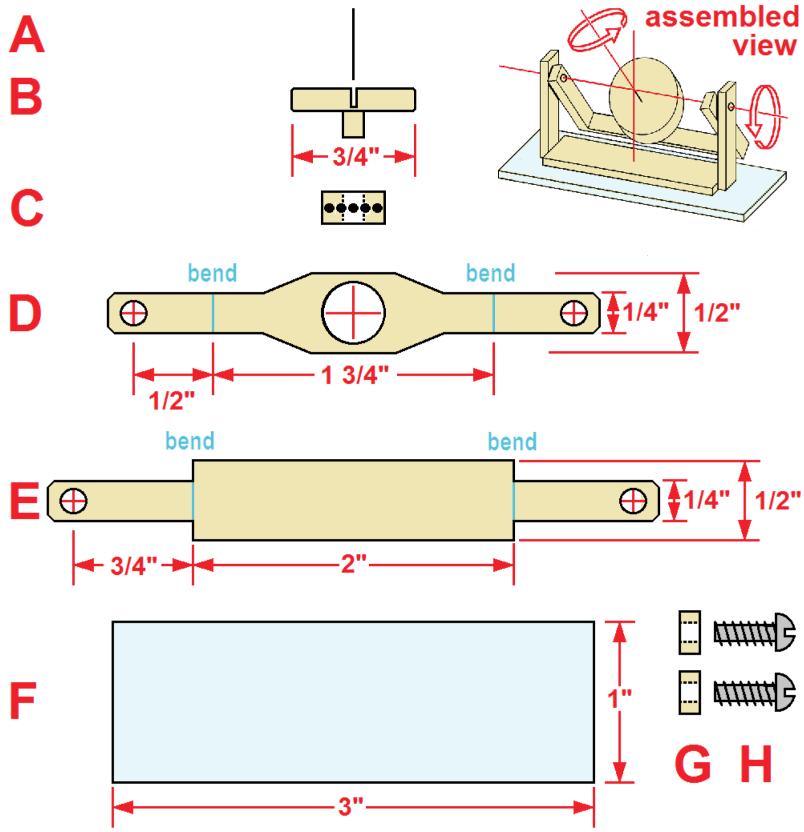


Figure 6 shows plans for the small two-axis stage. It is low profile, and is built on a 1 inch x 3 inch glass microscope slide. The cradle assembly is two 1/2 inch wide metal straps (Figure 6D, E) whose ends are bent to form U-shapes. The steel screws self-tap when screwed through the soft metal, no thread cutting is necessary. The cradle is epoxied to the glass microscope slide. A small bearing (Figure 6C) is epoxied to the inner cradle and holds the wheel and mounting pin. The mounting pin (Figure 6A) is epoxied into a hole drilled in the top of the wheel (Figure 6B); the tip of the needle is brought into the axes of rotation under the stereo microscope before the epoxy hardens.

Using The Stage. A specimen can be fastened to the needle with gum tragacanth in any orientation, then adjusted to the proper orientation with the stage's movements. A third axis provided by the microscope's rotating stage allows the oriented specimen to be aligned square to the edges of the photo frame. If the microscope stage doesn't rotate, the camera can usually be rotated to achieve the same effect. On a Greenough-style stereo microscope, orient the specimen using the viewfinder or computer screen, not the eyepieces. The tilting stage compensates for the microscope's inclined optical path, giving a rectilinear view and correcting the leaning problem illustrated in Figure 1D. If you photograph multiple focus levels with a Greenough-style scope, images are laterally displaced from frame to frame, but that is automatically corrected by image stacking software.

Platform Accessory

The removable platform accessory (Figure 7) is used with objects too big to balance on the end of the mounting pin. The platform is a 5mm diameter disk with a hollow shaft glued to its underside. The shaft is placed over the mounting pin; this is done with forceps while observing through the stereo microscope. Large specimens can then be temporarily glued to the platform. A suitably small diameter shaft is available as the tip of a technical drawing pen (eg: Rapidograph, or disposable Micron pen). With the platform in place, the universal stage recreates Beck's (1865) Opaque Disk-Revolver.

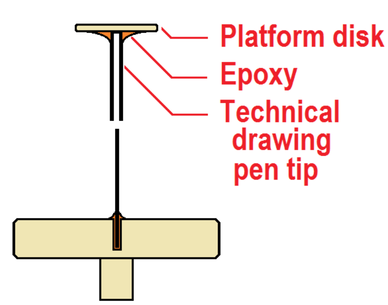


Figure 7. *Platform accessory for either the large 3-axis stage or the small 2-axis stage. The hollow shaft fits over the mounting needle; the platform provides a mounting surface for large unwieldy specimens.*

Adapt An Insect Stage

A commercial Insect Stage (Figure 8) is a convenient, almost ready to use, universal stage. Insert an insect pin (no insect attached) in the holding block so the pin lies in the vertical axis, and its head is in the horizontal axis. Leave it permanently in this configuration, and glue your specimens to the head of the pin. This adaptation makes a large two-axis stage for stereo microscopes; movement isn't as fine as a ball bearing stage.

Figure 8. *Insect Stage (BioQuip).*

Suppliers of Insect Stages include:

Australian Entomological Supplies: http://www.entosupplies.com.au/?path=1_3_52_66
BioQuip: http://www.bioquip.com/html/view_catalog.asp (see catalog page 21)
Rose Entomology: http://www.roseentomology.com/Pinned_Specimen_Manipulator.htm

A Final Example

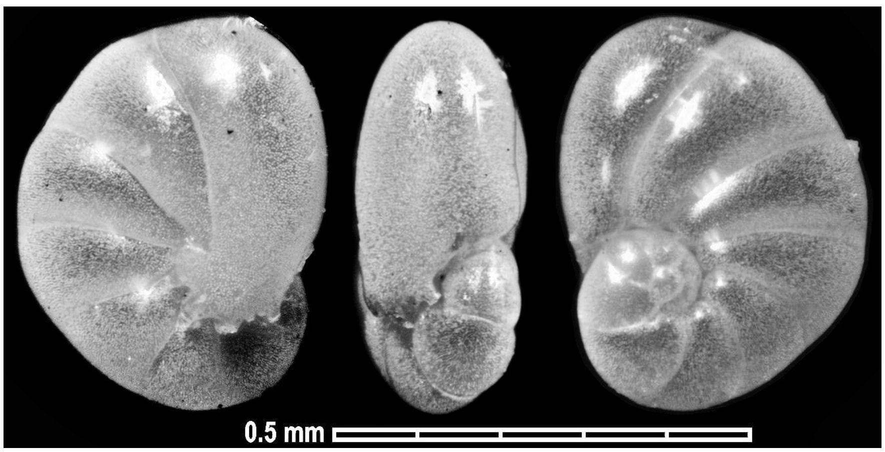


Figure 9. *Three views of a present-day specimen of Nonionella stella from Cholmondeley Sound, Prince of Wales Island, southeast Alaska, collected from a depth of 50 feet in anchor mud. Thanks to the universal stage, specimen orientation is better than in Figure 1. This interesting shallow to mid-depth species tolerates low-oxygen conditions such as found in California's Santa Barbara Basin, where it can dominate foram populations. Recent studies suggest this tolerance is related to symbionts held within its test. Images are computer composites of 39 to 42 focus levels made with Zerene Stacker image stacking software. Zoom in to see detail.*

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