In Search of a Practical Map Fold

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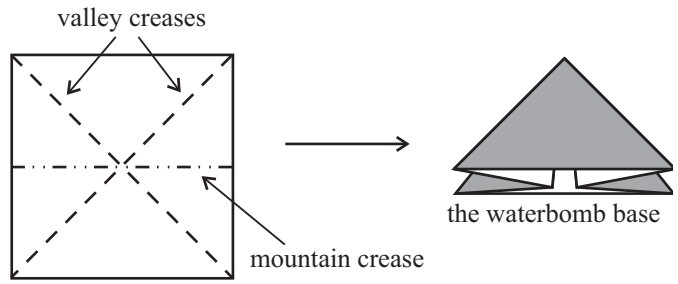
[This unique map folding] would give a soldier quite an advantage and maybe it was kept secret. [My friend who was in Desert Storm] related what a pain it was to stop, unfold the map and then refold it each time, all the while making a big white target for the enemy to shoot at.

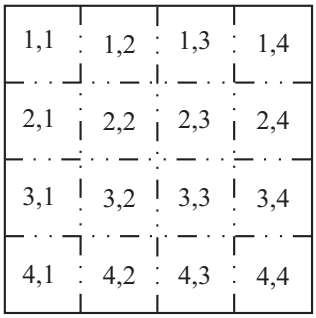
In the history of origami there has been occasional mention of how various people folded maps. Examples of ancient folded maps can be found, but modern paper-folders have been searching for "better" map folds than the awkward, fold in half over and over again method. One notable example is the Miura map fold, invented by Professor Koryo Miura of Japan, which can be opened and closed easily merely by separating two opposite corners. Such a trick is not a mere novelty; Miura has used his map fold to design solar panel arrays that can be opened and closed easily in space satellites. Other map folds exist that are sold commercially. I have seen one subway map that opens and closes using an array of pleats along the side.

But I had never thought of other, more practical possibilities for map folds until I received the following email:

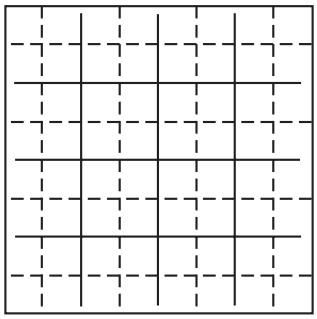
> Dear Sir:
>
> Is there a way to fold a large map that enables the user to view a conveniently small section of it, but also to view adjacent sections of the map with minor manipulations? This question was raised by one of my fellow medical students. I had shown him an origami tessellation and he was impressed with my folding technique, though I told him I got it off the internet. My friend was in Desert Storm. He was an Army jeep driver for a general. There was another general who had his own jeep driver but this other jeep driver knew this great way to fold maps. He was able to take a large map and fold it so that his general, in the jeep, could look at one section of it, and then with minor manipulations, look at adjacent sections without having to unfold it. My friend claimed that this manner of folding could allow the user to go to sections of the map both North, South, AND East and West. This was quite a feat, because the map could be used as the jeep was being driven around, with wind blowing. The other jeep driver was very jealous of his map folding and would not share it because it gave him a step up above all the other jeep drivers and made his general more efficient than the other generals.
>
> I asked my friend if there were diagonal folds and he said that he thought so, but he never got closer to the other's maps than two jeeps parked side by side, as generals compared notes. I asked if there were cuts in the maps, he said there might have been but he didn't remember any. He said that maps tended to wear out and break at the creases. My friend suggested that I come up with something because I was obviously interested in origami.
>
> I then called up another friend of mine who was also in Desert Storm…. My second friend had not heard nor seen anything like this map folding description but said that it would give a soldier quite an advantage and maybe it was kept secret. He related what a pain it was to stop, unfold the map and then refold it each time, all the while making a big white target for the enemy to shoot at.
>
> Have you heard of anything like this? Do you have any ideas? I suspect that it might be topologically impossible, but I am not sure.
>
> Sincerely,
>
> Shannon S. Roberts

Needless to say, I was intrigued! This seems like such a logical map-folding problem, yet I had never encountered it before. I had never heard of the requirement that the map be folded up and have it be easy to access other, neighboring parts of the map.

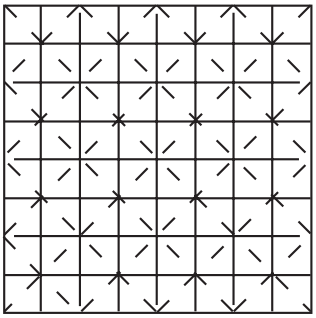




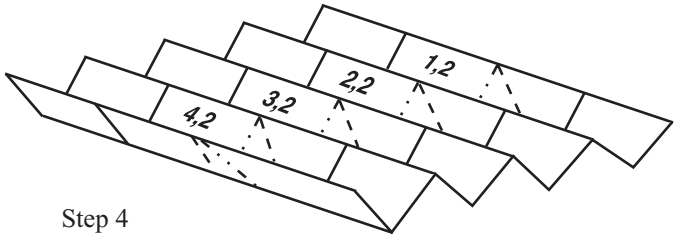
Step 1



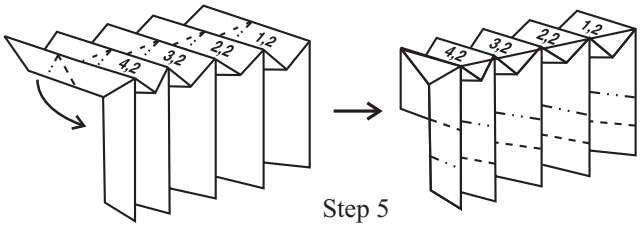
Step 2



Step 3



Step 4



Step 5

In this article I'd like to share a solution to this practical map folding problem that I devised. So read no further if you'd like to try thinking of a solution on your own.

The Waterbomb Base Solution

Being an origamist, as well as a mathematician, I immediately thought that I could use waterbomb-base collapses to hide parts of the map that I didn't want to see. A waterbomb base is a classic origami sequence which folds the paper along the diagonals using valley creases and along the middle using a mountain crease to collapse the paper into a layered triangle, as shown. (Note the two different types of dashed lines that we use to distinguish valley and mountain creases. These are standard symbols in origami books.)

The thing that attracted me to the waterbomb base for this project was the fact that it tessellates quite well. That is, it is possible to fold a grid of waterbomb bases on one sheet of paper. Take a standard tiling of the plane with squares and imagine putting the waterbomb base crease pattern into each square (you might need a vertical mountain crease in each waterbomb as well). This would be your crease pattern, and amazingly enough, it can collapse into a flat object! Furthermore, these waterbombs would be easy to open and close to reveal different parts of the paper. Thus, if we tried folding a map in this way, we might have a folded map like the one Shannon's friend described.

Now, describing this fold and actually folding it are two different things. What follows is a description of how to fold a square map (though the same technique will work for rectangular maps) in this way, using a 4×4 grid of tessellated waterbomb bases.

Step 1: Fold the map (map side up) into fourths horizontally and vertically, making the creases mountain folds. In these pictures I'll label the 16 sections of the map-grid (x, y) where x is the row and y is the column, each going from 1 to 4.

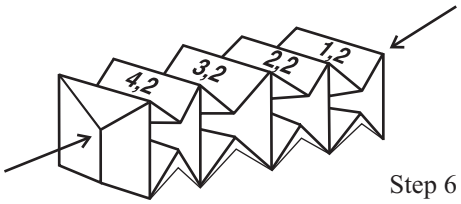
Step 2: Make valley creases at the 1/8th marks, horizontally and vertically.

Step 3: Make a bunch of diagonal valley creases. You're only dividing each diagonal into 8ths, so you won't hit every intersection with these diagonals. Can you see the 16 waterbomb bases?

All the creases are now in place. All that remains is to collapse it! This isn't very easy, and it needs to be done in the right way. (But there is a lot of variability—the map will still work even if some of the layers are put in awkward places.)

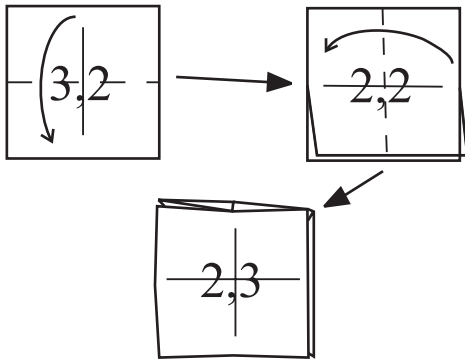
Step 4: Accordion pleat the paper along the horizontal creases. I've labeled the column (1, 2) through (4, 2) as a reference mark.

Step 5: The paper to the right of the (1, 2)–(4, 2) column needs to be reversed down. Step 4 has dashed lines indicating where some of the mountain and valley creases are placed. The paper should look like the left side of the figure after this step.



Step 6

Step 6: Reverse the paper to the left of the (1, 2)–(4, 2) column in the same way, as shown in the right picture of Step 5. At this point the paper to the left of the (1, 2)–(4, 2) column is in place and ready to go. The right side needs to be collapsed some more. Make the mountain crease between columns 3 and 4 (as shown in Step 1) and make the valley down the middle of column 4. (This will require opening it all up a bit.) Then waterbomb base collapses can be made in the 3rd column squares… Your model, at this point, might not look exactly like the drawing in Step 6, depending on how you choose to arrange the layers. Persevere and flatten the whole thing into one square. At this point any one of the second column squares can be revealed easily. So, if you open the (3, 2) square you should be able to "book fold" one layer down to reveal the (2, 2) square. Then try folding to the left to get (2, 3)!



It's not very easy, is it? To get to (2, 3) you'll have to open up one of the waterbomb base collapsed squares. This might be doable with no resistance, or you may have to slide some layers around underneath to see (2, 3) and get it in the proper orientation. This all depends on how you collapsed everything down.

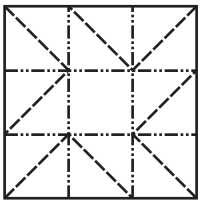
I'm not sure how satisfied Shannon Roberts would be with this solution. It is possible to carefully arrange the layers so that if you're looking at, say, (2, 2) then you can easily go North and South with book folds and go East and West by opening waterbomb collapses. This can easily be done with one hand and would probably serve the needs of army jeep generals.

However, if you get used to the manipulations, you can learn how to quickly go from one square on the grid to any other, as opposed to just going N, S, E, or W. I'm not sure if that's what Shannon claims the Desert Storm soldier could do, and it may be awkward doing this with one hand while bullets are flying around.

But this leads to many wonderful questions and thoughts!

- Can a three-axis version be made with a hexagonal tile grid, instead of a square one? I don't think it can without sacrificing parts of the map to the mechanism, which can then never be viewed.
- Might this have a nice application for storytelling? Imagine having a large version with pictures drawn on every square. A story could be told, showing one square at a time. The audience would be bewildered at how many pictures were hidden in the fold! It might even look like a magic trick if done properly.

There are other solutions to this map folding problem as well. Stephen Canon, a math major at Brown University, came up with a solution that is based on the mechanics of the square twist. Here is a crease pattern that works for folding a square map into a 3×3 grid (taken with permission from his web page `http://www.math.brown.edu/~scanon/Origami/map.html`):



See if you can collapse this! Stephen Canon's method can be expanded to fold a square map into any $n \times n$ grid, but like the waterbomb base method I described above, the layers of paper get very unwieldy as the grid gets bigger.

It remains an open question whether or not the United States Army feels that such map folds are vital to our nation's security. But it does offer a great example of how geometric origami can turn out to be useful in surprising settings. ■

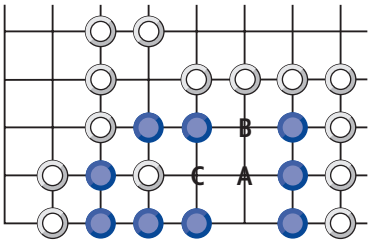


Figure 12. Solution to Challenge Problem from p. 19
White must first play at A. Blue is compelled to play at B to keep white's stones separated. But then white plays C and blue cannot form two eyes. If blue ever captures the three white stones, white must immediately play back at C. Thus blue's stones are essentially dead once white plays at A.