# Girih Tiling Patterns in Google SketchUp

As far back as the 13th century, Islamic architecture has featured amazing and intricate geometric patterns.

Historians and mathematicians had assumed that the craftsmen who created these patterns did all their work with compasses and straight edges. But a few years ago, it was discovered that many of these patterns were actually made using a set of five repeating tiles, called girih tiles. (The story of this discovery by Peter Lu and Paul Steinhardt is very interesting; read about it at http://www.nytimes.com/2007/02/27/science/27math.html.)

"Girih" is Persian for "knot," and refers to the straight lines that run through these tiles, forming what's called "strapwork." The strapwork is usually what you see on these buildings; the actual borders of the tiles don't appear. For an example of this, look at the stone piece to the right. On the left side you can see strapwork, and on the right side you can make out an overlay of the tiles that contain the strapwork.
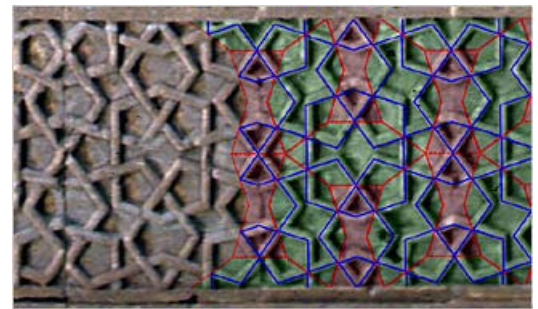
A geometric description of these tiles can be found on Wikipedia: http://en.wikipedia.org/wiki/Girih_tiles.

Girih tiles
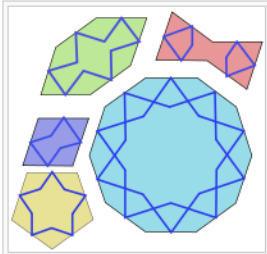
From Wikipedia, the free encyclopedia

Girih tiles are a set of five tiles that were used in the creation of tiling patterns for decoration of buildings in Islamic architecture. They are known to have been used since about the year 1200 and their arrangements found significant improvement starting with the Darb-i Imam shrine in Isfahan in Iran built in 1453.
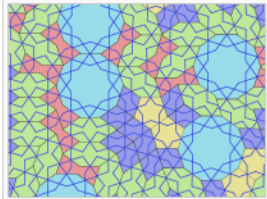
The five shapes of the tiles are:

- a regular decagon with ten interior angles of 144°;
- an elongated (irregular convex) hexagon with interior angles of 72°, 144°, 144°, 72°, 144°, 144°;
- a bow tie (non-convex hexagon) with interior angles of 72°, 72°, 216°, 72°, 72°, 216°;
- a rhombus with interior angles of 72°, 108°, 72°, 108°; and
- a regular pentagon with five interior angles of 108°.

All sides of these figures have the same length; and all their angles are multiples of 36° ($\pi/5$). All of them, except the pentagon, have bilateral (reflection) symmetry through two perpendicular lines. Some have additional symmetries. Specifically, the decagon has tenfold rotational symmetry (rotation by 36°); and the pentagon has fivefold rotational symmetry (rotation by 72°).

Girih are lines (strapwork) which decorate the tiles. The tiles are used to form girih patterns, from the Persian word for "knot".[1] In most cases, only the girih (and other minor decorations like flowers) are visible rather than the boundaries of the tiles themselves. The girih are piece-wise straight lines which cross the boundaries of the tiles at the center of an edge at 54° ($3\pi/10$) to the edge. Two intersecting girih cross each edge of a tile. Most tiles have a unique pattern of girih inside the tile which are continuous and follow the symmetry of the tile. However, the decagon has two possible girih patterns one of which has only fivefold rather than tenfold rotational symmetry.

An illustration of the Girih tiles

An illustration of patterned Girih tiles

In this project, we'll start with the five girih tiles, and learn a few ways to combine them into amazing patterns.

Girih Pattern 1

For this pattern, we'll move tiles together and rotate them into place.

1. To download the girih tiles used in this section, open the Google 3D Warehouse:
    http://sketchup.google.com/3dwarehouse. In the search field, enter "girih tiles." For the model shown below, click the "Download to SketchUp" link.


Here are the tiles in SketchUp: one decagon and one pentagon (each with a mark at its center), an irregular hexagon, a rhombus, and a shape known as a "bowtie." The edge lengths of each tile is identical. The lines inside each tile are the strapwork; each starts at the midpoint of an edge, and is 54 degrees from that edge.
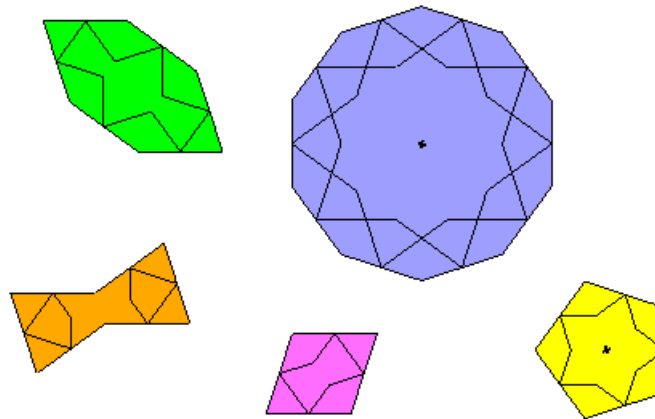
Each tile is a component, which means that if you change one, all copies of that tile will also change.

2. The first step is to join the irregular hexagon to the decagon. Activate the **Select** tool (shortcut key: Spacebar) and click the irregular hexagon tile to select it.
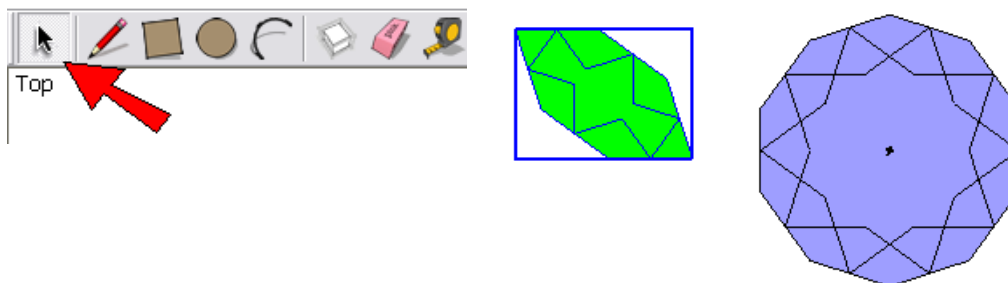
3.   Activate the **Move** tool (shortcut key: M), and click the hexagon corner shown below.
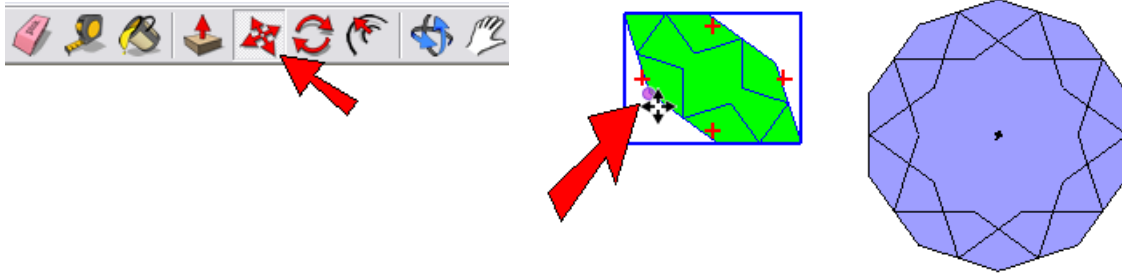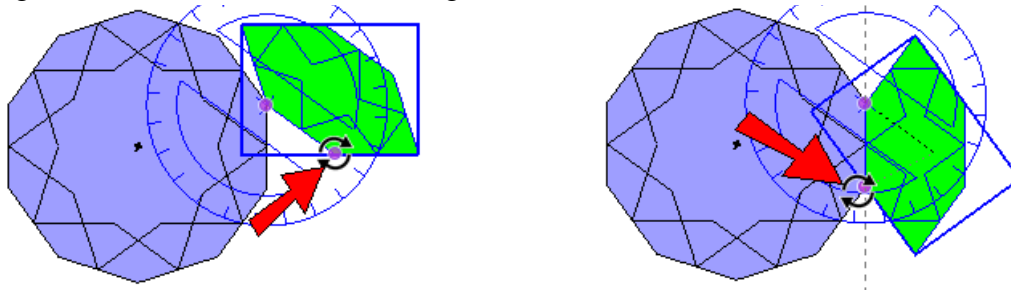

4.   Move the hexagon to the decagon corner shown below.
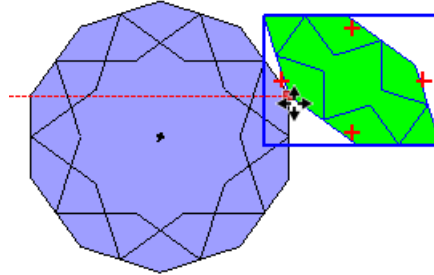
5.   The hexagon now needs to be rotated into place. So keep it selected and activate the **Rotate** tool (shortcut key: Q). Click to place the protractor at the point where the two tiles meet.
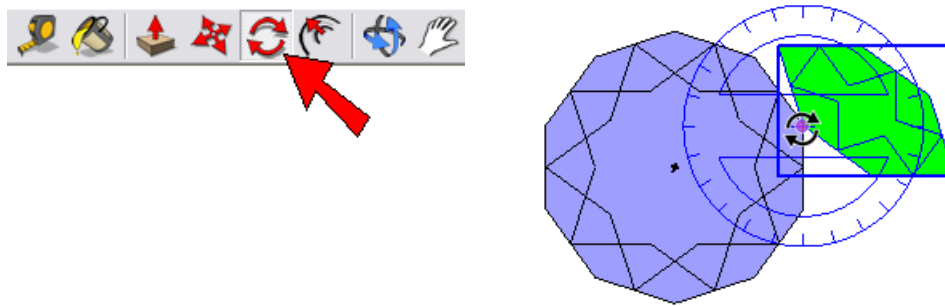

6.   The next two clicks define the rotation angle. First click the hexagon corner shown below on the left, then click the decagon corner shown below on the right.

7. Another decagon will now be placed to the right of the hexagon. This time, select the decagon, and activate **Move**. Press the Ctrl key (PC) or Option key (Mac), which means a copy will be created. For the first move point, click the decagon corner shown below on the left, and for the second move point, click the hexagon corner shown below on the right.
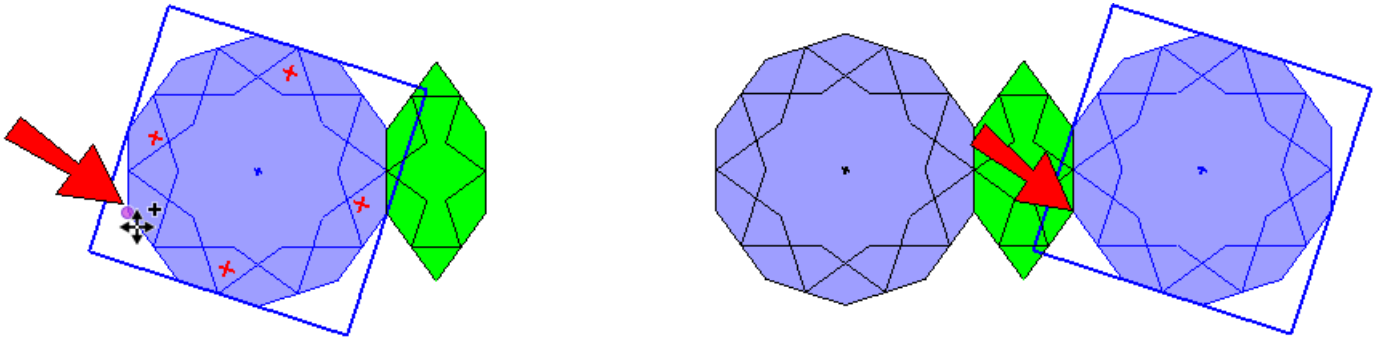
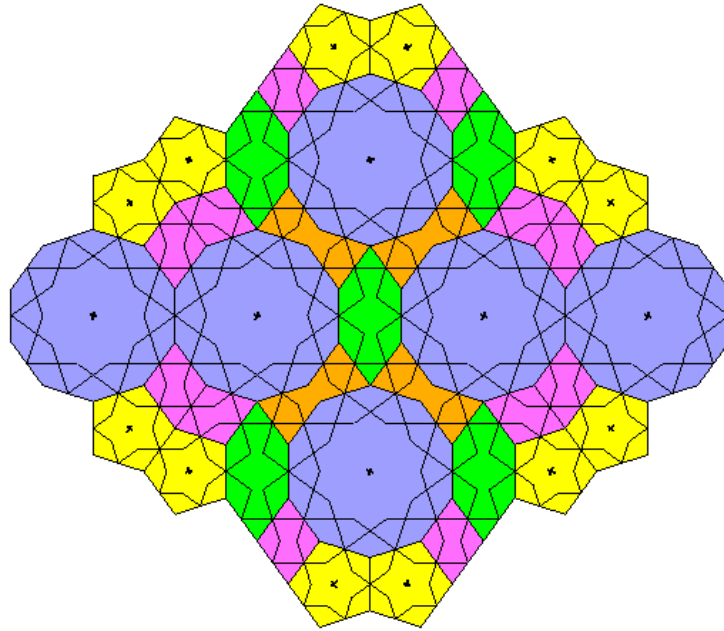8. Now we'll add some bowties. Use the **Move** and **Rotate** tools to add four bowties to the pattern:
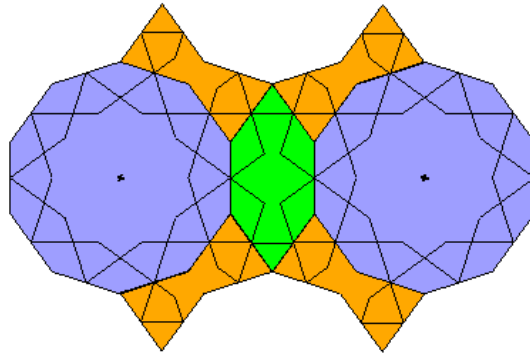
*If you're good at using the **Rotate** tool to make rotated copies, you can save yourself some work!*

9. Then bring in four rhombi on each side, plus two more decagons.
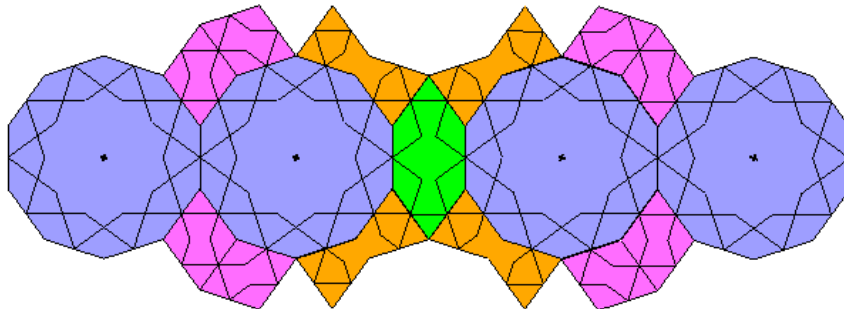
10. Keep adding to the pattern, until you get this:

You could keep adding more and more tiles to this pattern, but let's move on to the next one...

Girih Pattern 2

This pattern will introduce rotated copies.

1. Start in a new file containing only the five tiles, and arrange one decagon, bowtie, and hexagon like this:
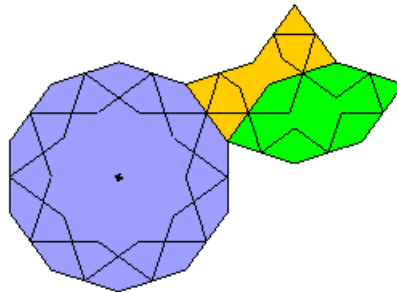

*The pentagon and rhombus aren't used in this pattern, so you can erase them.*

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2. The bowtie and hexagon will be rotate-copied around the decagon, which is why the center of the decagon was marked. First, select both of these tiles (press Shift when you want to select multiple objects). Then activate **Rotate** and place the protractor at the center of the decagon.
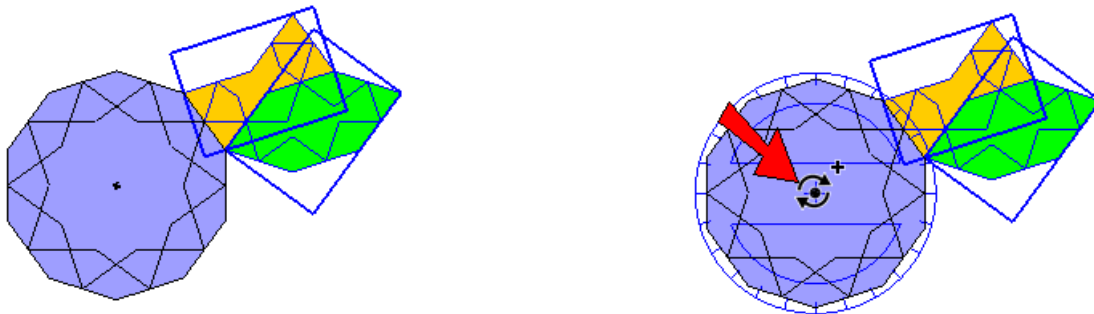
3.   Press Ctrl / Option to make copies. For the first rotation point, click one corner of the decagon, and for the second rotation point, click an adjacent decagon corner. The rotation angle should be 36 degrees (one-tenth the angle around a circle).
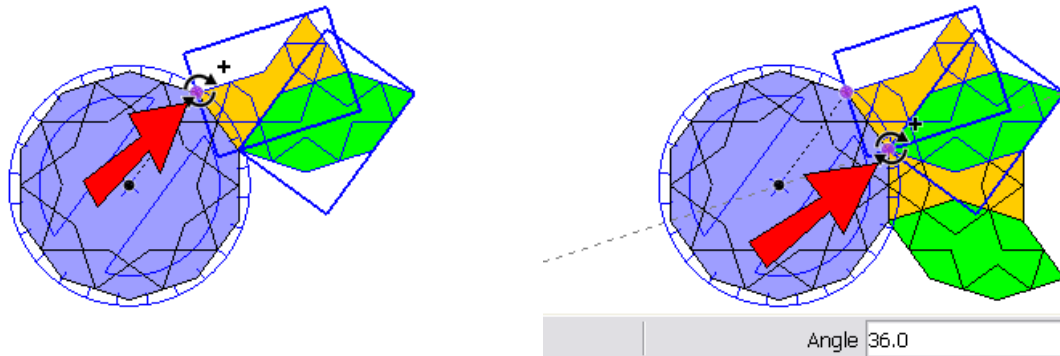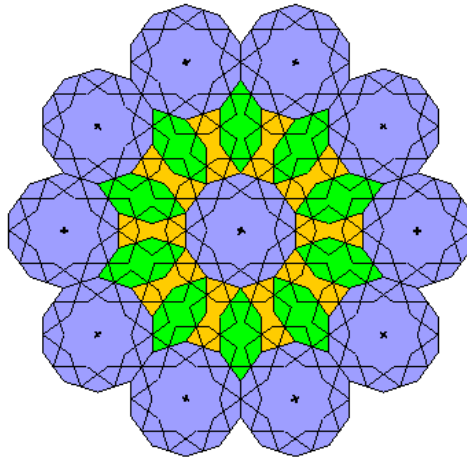

4.   After the first copy is made, type 9x and press Enter. This creates 9 copies, for 10 total sets of tiles.
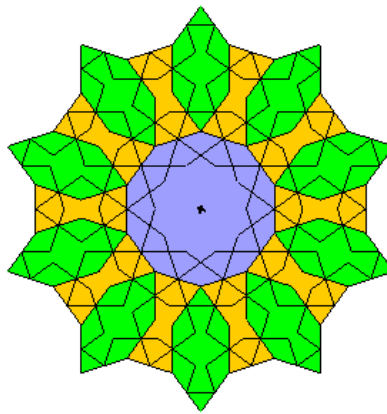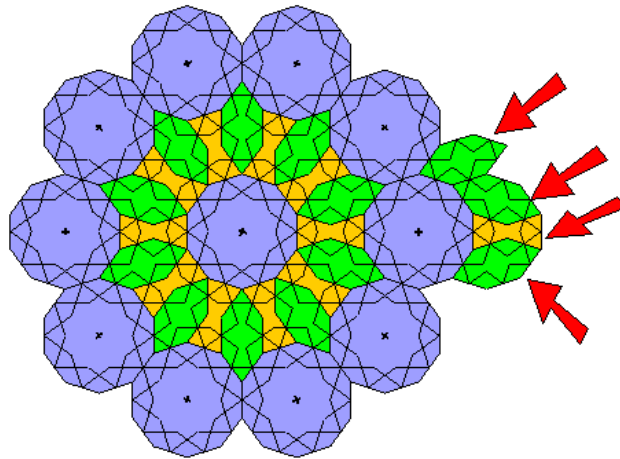

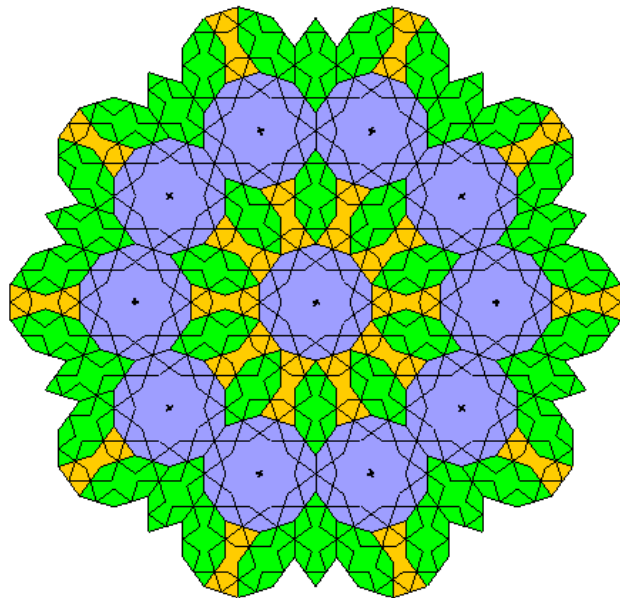5.   To continue building outward, add a decagon here:
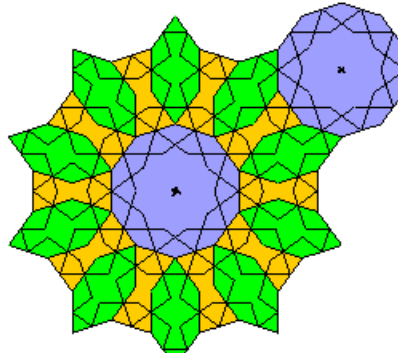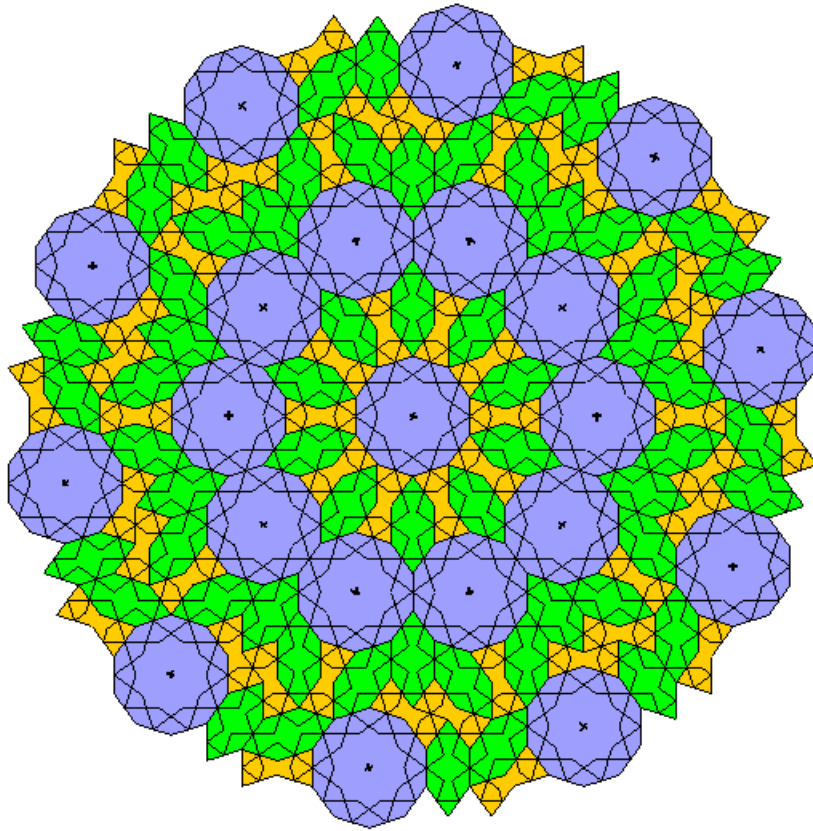
6.   Select and rotate-copy this new decagon around the decagon in the center.

7.   The next ring consists of these four repeating tiles:

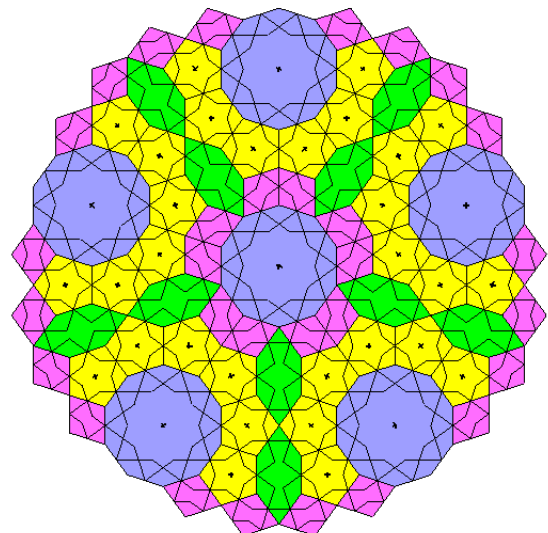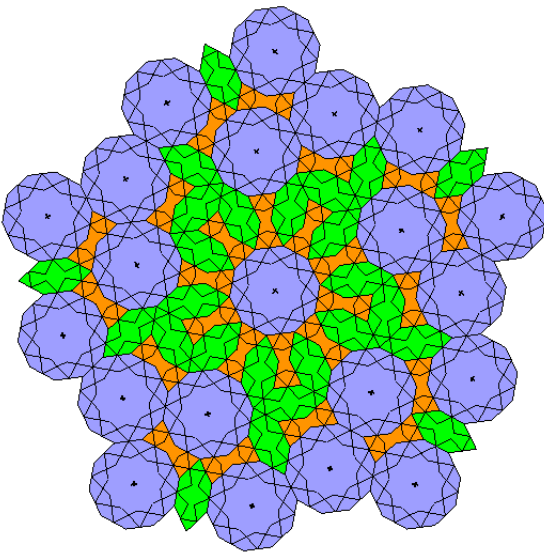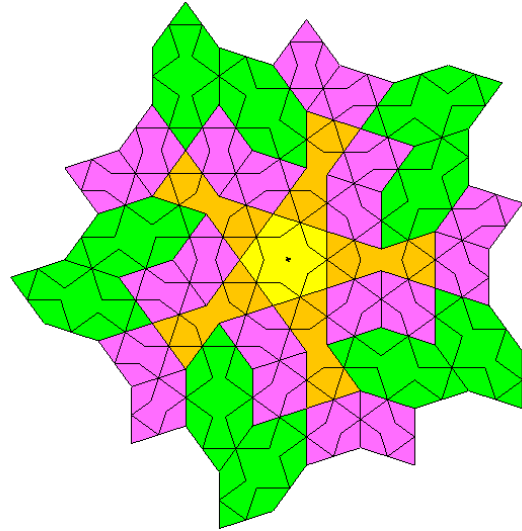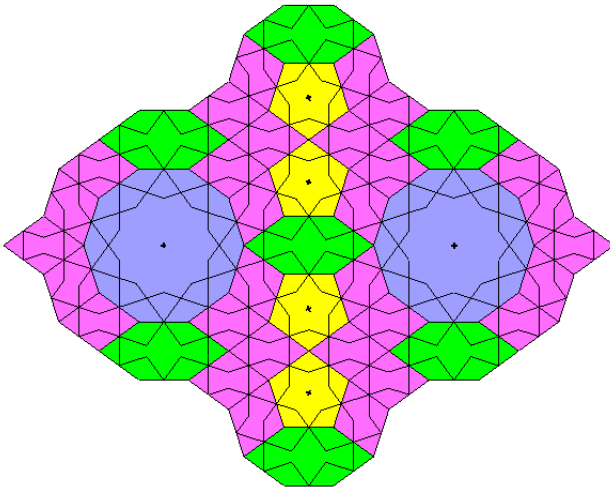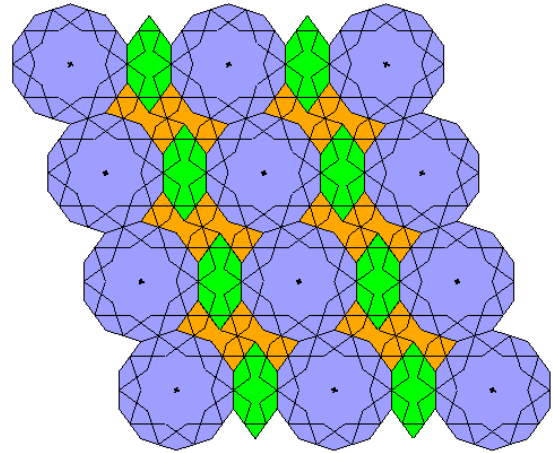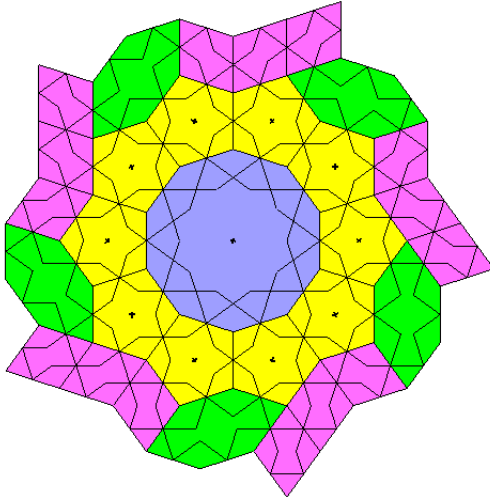8.   Here's how it looks after the four new tiles are rotated-copied:

9.   Again, you can keep adding tiles infinitely, but I stopped here:

Try These Patterns

There is an infinite number of ways you can combine these five tiles. In addition to the two already described, here are six more you can try. You should also try to create your own!

But Wait, There's More!

Because these tiles are components, there are endless ways to make your patterns even better. There are a few ideas presented here, which you can try out on any of your patterns.

1. Before making any changes, choose **Window / Model Info** from the main menu. In the **Model Info** window, open the **Components** page, and uncheck both **Hide** boxes. This means that when you edit a component, everything else in the model will be temporarily hidden from view. Then close the **Model Info** window.
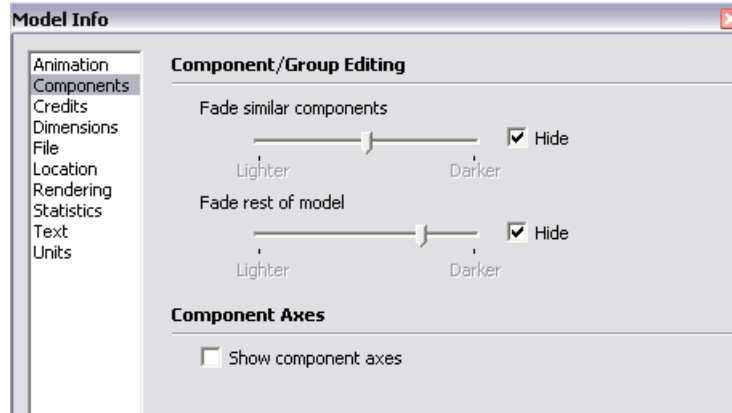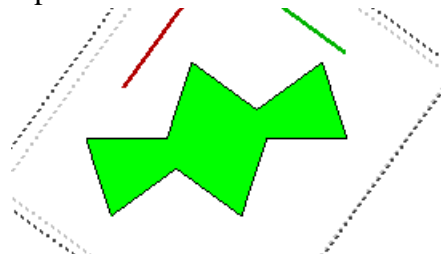

2. Right-click on any tile and choose **Edit Component**.
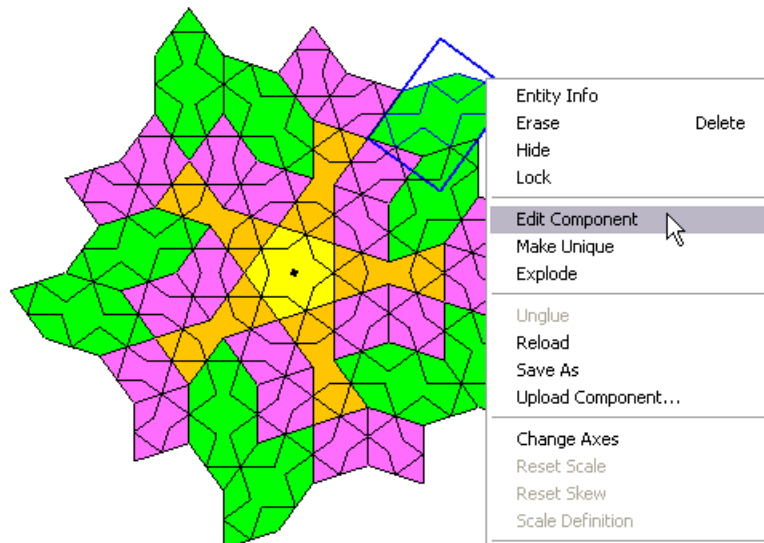
That tile is now open for editing, and everything else in the model disappears.
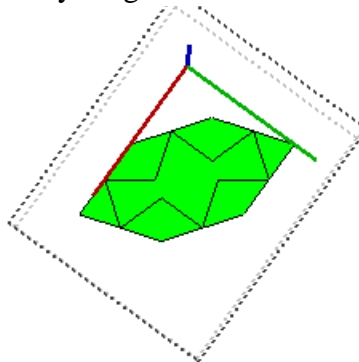
3. From the girih description on the first page of this project, remember than the strapwork is what appears in most Islamic architecture, not the tiles themselves. So activate the **Eraser** and erase the outer border of this tile, leaving just the edges of the strapwork and the face inside.


4. Right-click outside the tile and choose **Close Component**. This brings back the other tiles, and you can see that every similar tile has been changed.
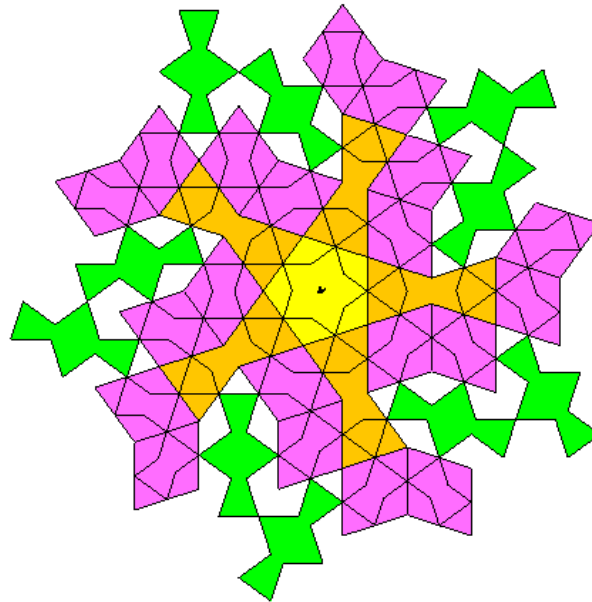

5. Edit each of the other tiles the same way: open one for editing, erase its outer border edges, and close the component.
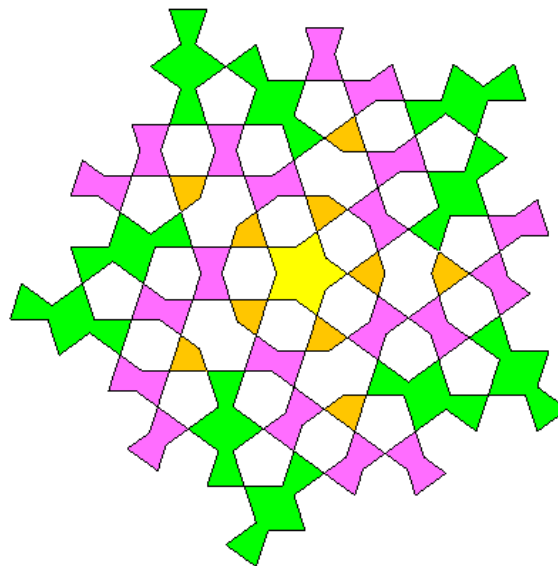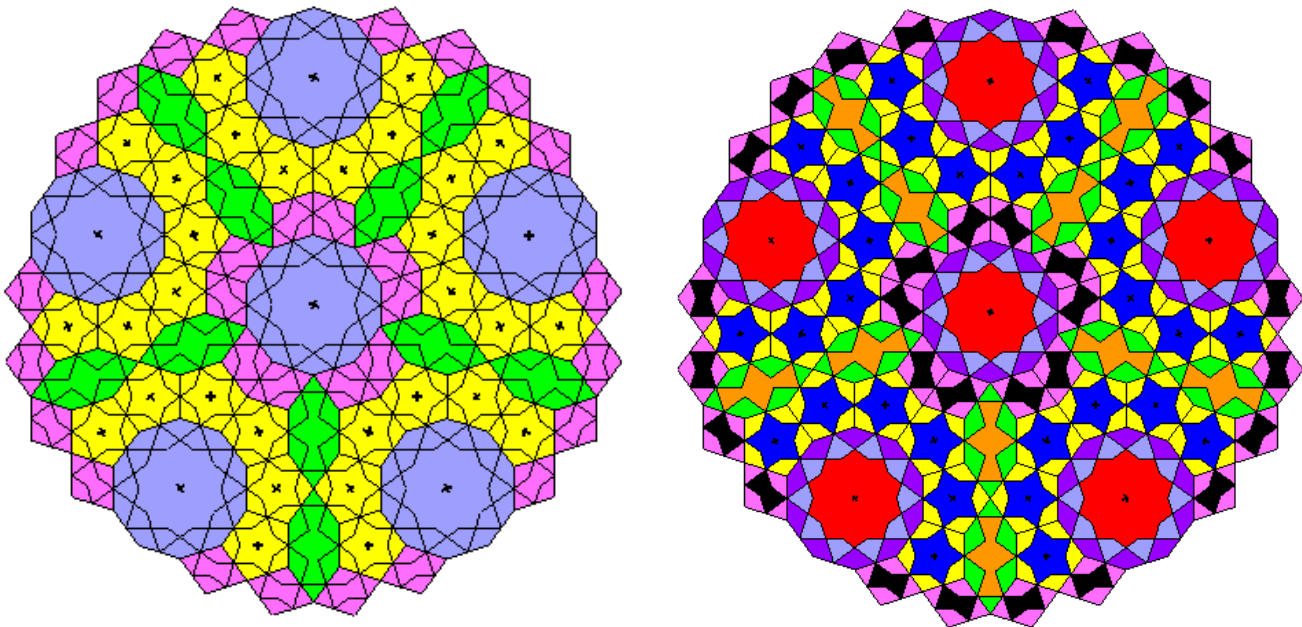
6. This leaves a lot of blank space, which is easy to fill in. Select all of the tiles (use Ctrl+A or Cmd+A), right-click on any selected tile, and choose **Explode**.
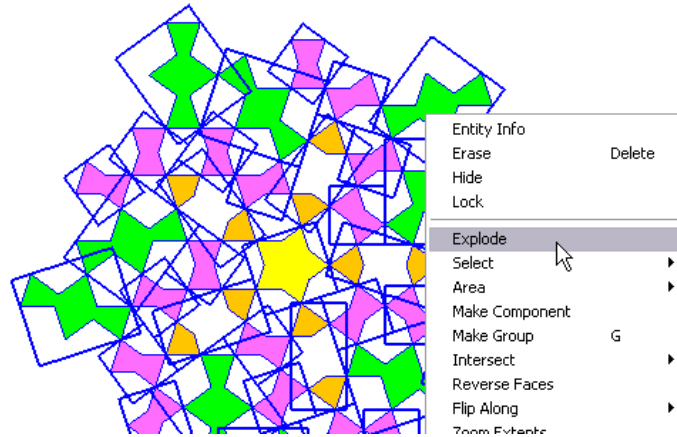
7. Then use **Line** to trace one edge of each blank space. This fills in the missing faces, which you can then paint.
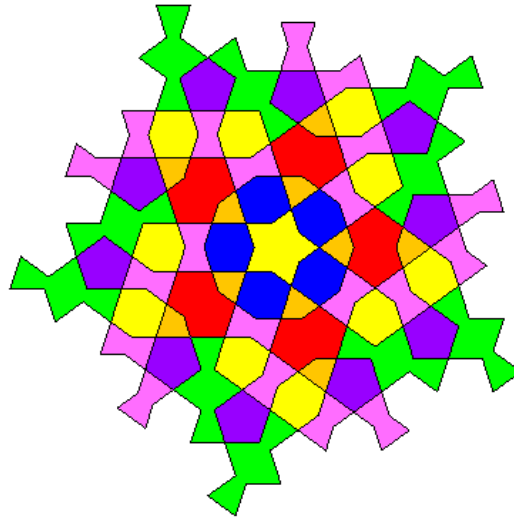
Here's another idea: leave the tiles as they are (don't erase edges), but edit each one and change its colors.

And for a really cool pattern, edit each tile to contain just its strapwork, use **Offset** to create frames, use **Push/Pull** to make the frames 3D, and paint each interior face with a translucent material.