"Barometer up and humidity down.
One of those crystal-clear nights
when the stars fairly crackle —

Glass Giant of Palomar
David Woodbury 1939
George Ellery Hale

George Hale (1868-1938) had a remarkable life.

His contributions to solar spectroscopy, such as his invention of the spectro-helioscope that imaged the Sun at different wavelengths, were surpassed by his vision and drive to design and construct the largest telescopes in the world.

Birth of the 200"

The 100" Hooker telescope was operational in 1918.

Hale now thought bigger... More light!

In 1928 he approached the Rockefeller Foundation and persuaded them to pledge $6 million to build the 200" telescope and observatory.
Telescope Mounts

Hale did not want the 200" telescope to suffer from the same limitations as the 100" Hooker telescope.

The English (yoke) mount meant that no observations could be made within 30° of the north celestial pole.

More importantly, the plate glass mirror expanded and contracted with changing temperatures, distorting the mirror surface.

Horseshoe Yoke Mount

Can the 100" mirror be scaled up to make a 200" mirror?

Using plate glass would result in the same distortions with changing temperature, so Hale decided on the use of low-expansion glass.

To avoid having a mirror 8 times heavier, it would need to be made with innovative glass-pouring techniques.
Making a Mirror

An empty mould results in a slab of glass that is roughly flat on its top and bottom surfaces.

After cooling to room temperature the glass slab can be ground down to make a curved surface and then coated with a thin layer of aluminium.

Making a Ribbed Mirror

If the mould is first filled with 'cores' made of fire bricks then the glass flows around them.

When the mirror has cooled the cores are removed.

The result is mirror with a front surface as before but now with a ribbed back, making it lighter and stronger.

Mirror Section

Mirror Mould
Casting the Mirror

First Mirror

The first mirror blank was ruined by pieces of the mould floating to the surface, and by fire bricks falling from the inside wall of the annealing oven onto the mirror surface.

These problems were fixed for the casting of the second blank.
Corning Advert

Creating the 200" mirror blank from low-expansion Pyrex glass took years of innovation on the part of Corning.

After overcoming problems with the annealing ovens, dealing with a flood of the nearby river and even an earthquake, they were keen to promote the successful casting of the 200" mirror as their flagship project.

The Mirror Arrives at Caltech

1936

Grinding the Mirror Surface

21 Men – 11 Years
Mirror Vertical For Testing

As the mirror was slowly ground to the correct shape ('figured') it was checked using a 'knife-edge' test.

Observatory Building Takes Shape

Now it starts to look like an observatory

Constructing the Dome

"Resistance is futile"
Cutaway drawing of the 200" telescope and its observatory building by Russell Porter.

In this talk this drawing will be used as a guide to locate some parts of the telescope or mount or observatory.
Note the thickness of the curved steel plates forming the inside and outside surfaces.

The 4.5" thick plates were bent to shape in a 12000-ton forge press.
South Yoke

Looking like a huge telephone handset, the south end of the yoke is a bar with a hole for the south polar bearing in the centre.

Up To the Observatory

South Yoke Arrives

Horseshoe Arrives

Dr Steve Barrett

NAS 3 Oct 2019
Working on the Telescope Tube

RA Gear Wheel

Cutting the Gear Teeth

Russell Porter

The highly detailed drawings made by Russell Porter between 1937 and 1940 (some of which are shown in the next eight slides) give a unique insight into the design and construction of the 200" telescope.
**RA Drive**

Right Ascension Drive and "Computer", an analogue computer comprising gears and cams that was designed to vary the drive speed automatically to account for very small variations in the apparent positions of the stars, such as those produced by refraction of starlight through the Earth's atmosphere.

**Polar Axis Horseshoe**

The massive horseshoe bearing floats on four oil pads so that the friction is reduced to a thousand times less than would be the case for ball bearings or roller bearings.

**South Polar Bearing**

**Declination Drive**

The tubes of the yoke mount are hollow and one of them contains the declination drive motor.
Prime Focus Cage

Prime Focus Pedestal

The pedestal is in the top half of the prime focus cage where the astronomer sits to take photographs.

For long exposures it may be necessary to guide the telescope by watching a guide star and making small manual adjustments to the drive motors.

Prime Focus Mirrors

The bottom half of the prime focus cage contains mirrors that fold down into the light path when the astronomer wants to use the Cassegrain or the coudé focus.
Almost Complete?

Everybody thinks that the telescope is just months from being finished.

The telescope tube and mount are complete. The mirror has been ground to within a few millionths of an inch of the correct figure.

But ... it is 1941. The USA is about to be dragged into World War II.
Hale Telescope Today

Acknowledgements

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200@70

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Dr Steve Barrett

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