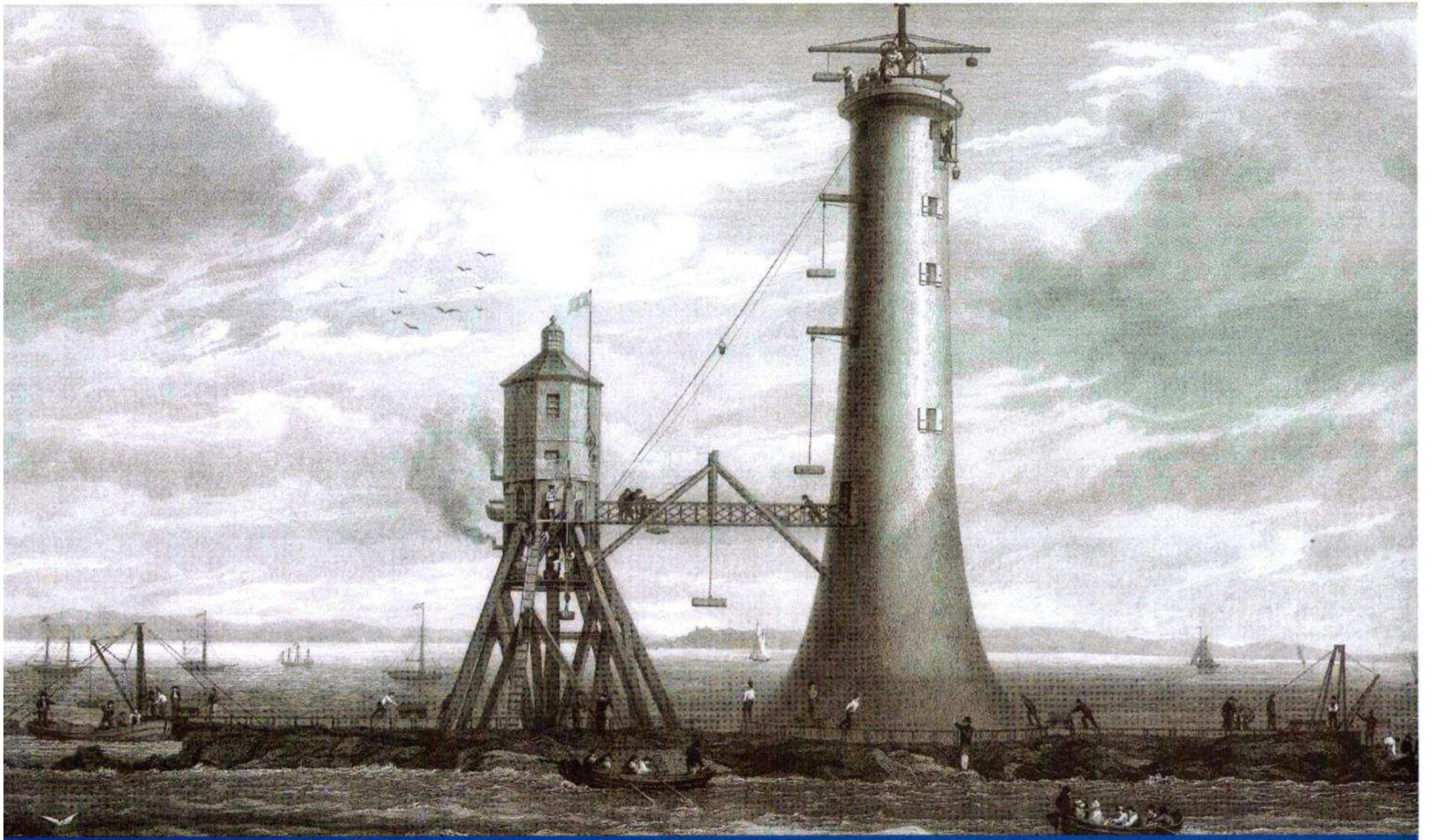


HISTORY OF THE BUILT ENVIRONMENT LECTURE 29 October 2010

CREATION OF THE BELL ROCK LIGHTHOUSE 1807-11

by Professor Roland Paxton MBE FICE FRSE

School of the Built Environment, Heriot-Watt University

Vice-chairman Institution of Civil Engineers Panel for Historical Engineering Works

SCOTLAND'S DANGEROUS UNLIT COAST

Northern Lighthouse Board [NLB] formed in 1786 to improve maritime safety

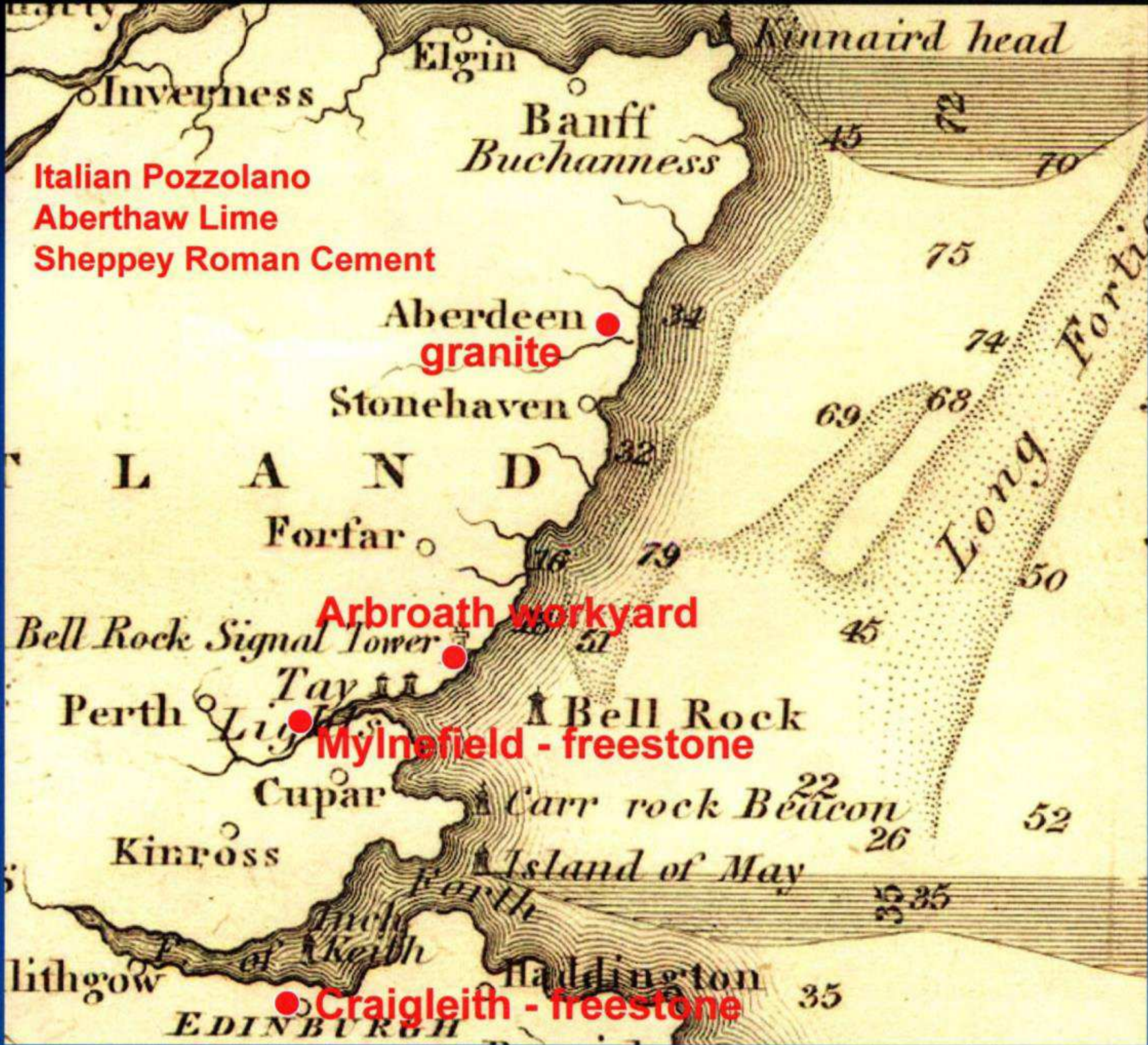
LAMP MANUFACTURER

Thomas Smith - Engineer

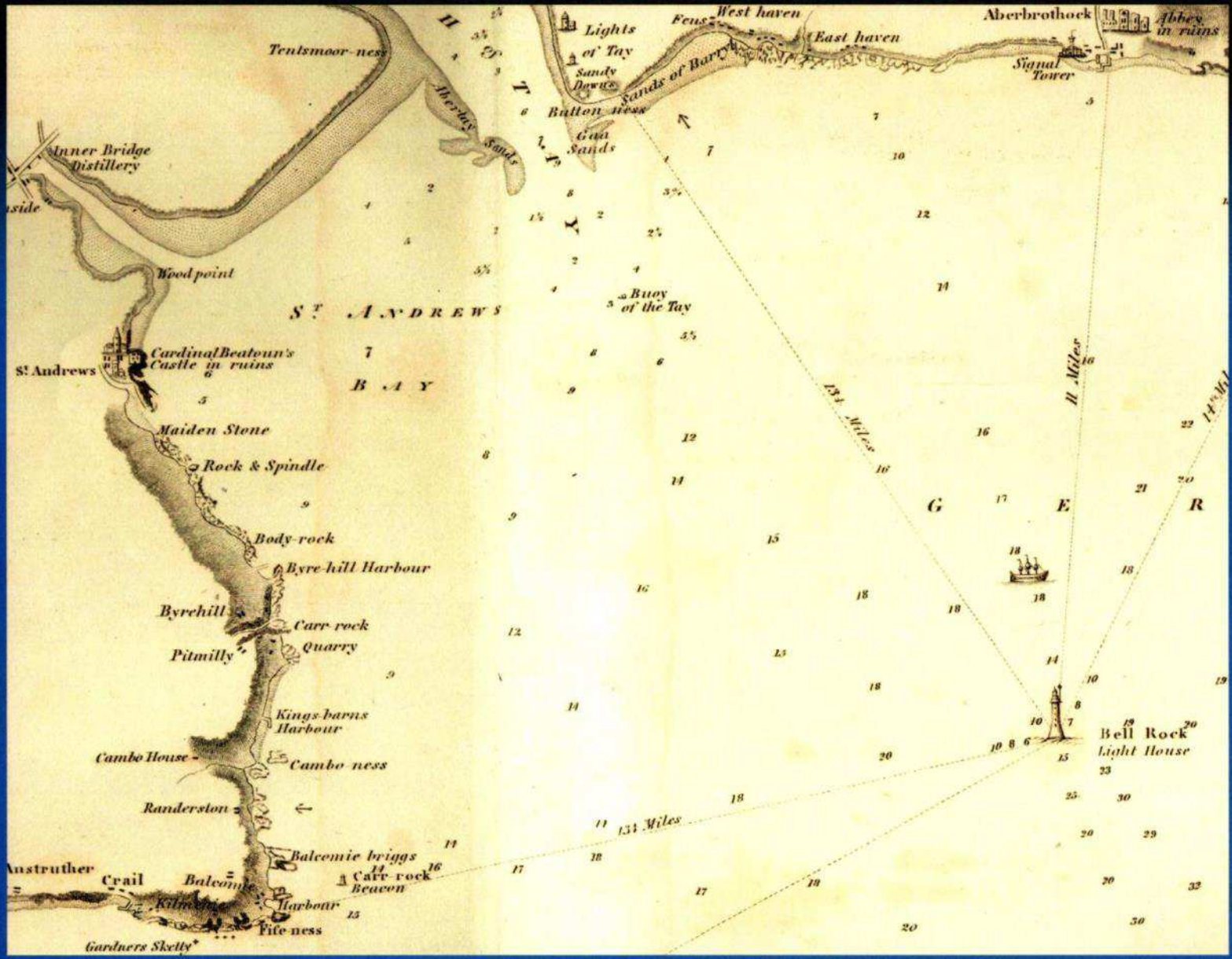
Kinnaird Head LH 1787
Mull of Kintyre LH 1788
N. Ronaldsay LH 1789
Island Glass LH 1789
Pladda LH 1790

1791 Robert Stevenson's career with Smith began

Little Cumbrae LH 1793
Pentland Skerries LH 1794
Cloch LH 1797.

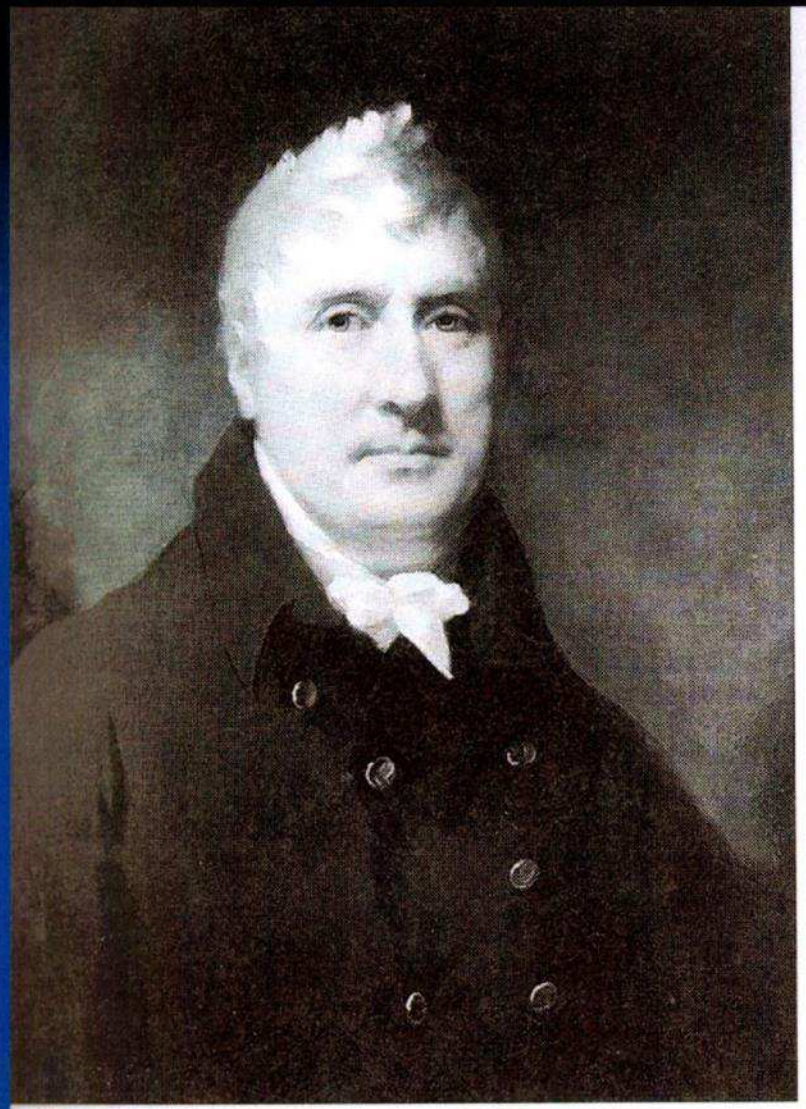


Italian Pozzolano
Aberthaw Lime
Sheppey Roman Cement
Kinnaird head
Elgin
Inverness
Banff
Buchanness
Aberdeen
granite
Stonehaven
L A N D
Forfar
Arbroath workyard
Bell Rock Signal Tower
Tay
Perth
Mylnefield - freestone
Bell Rock
Cupar
Carr rock Beacon
Kinross
Island of May
Forth
Long Forth
Haddington
Craigleith - freestone
EDINBURGH

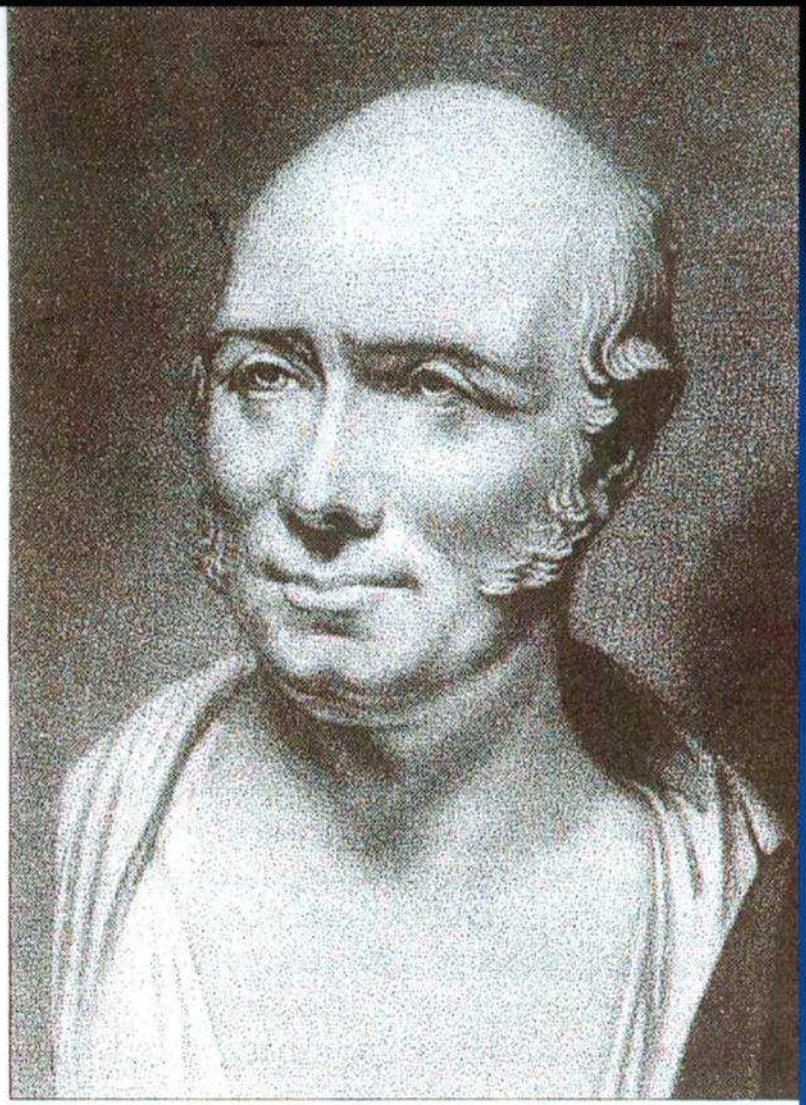


The hazardous Inchcape or Bell Rock 11 miles off Arbroath and 13 miles NNE of Carr Rock.

Bell Rock at low tide (1986) In 1799, 70 vessels were stranded or lost in the area, many of which might have been saved by a lighthouse here. Creating one was a daunting challenge.

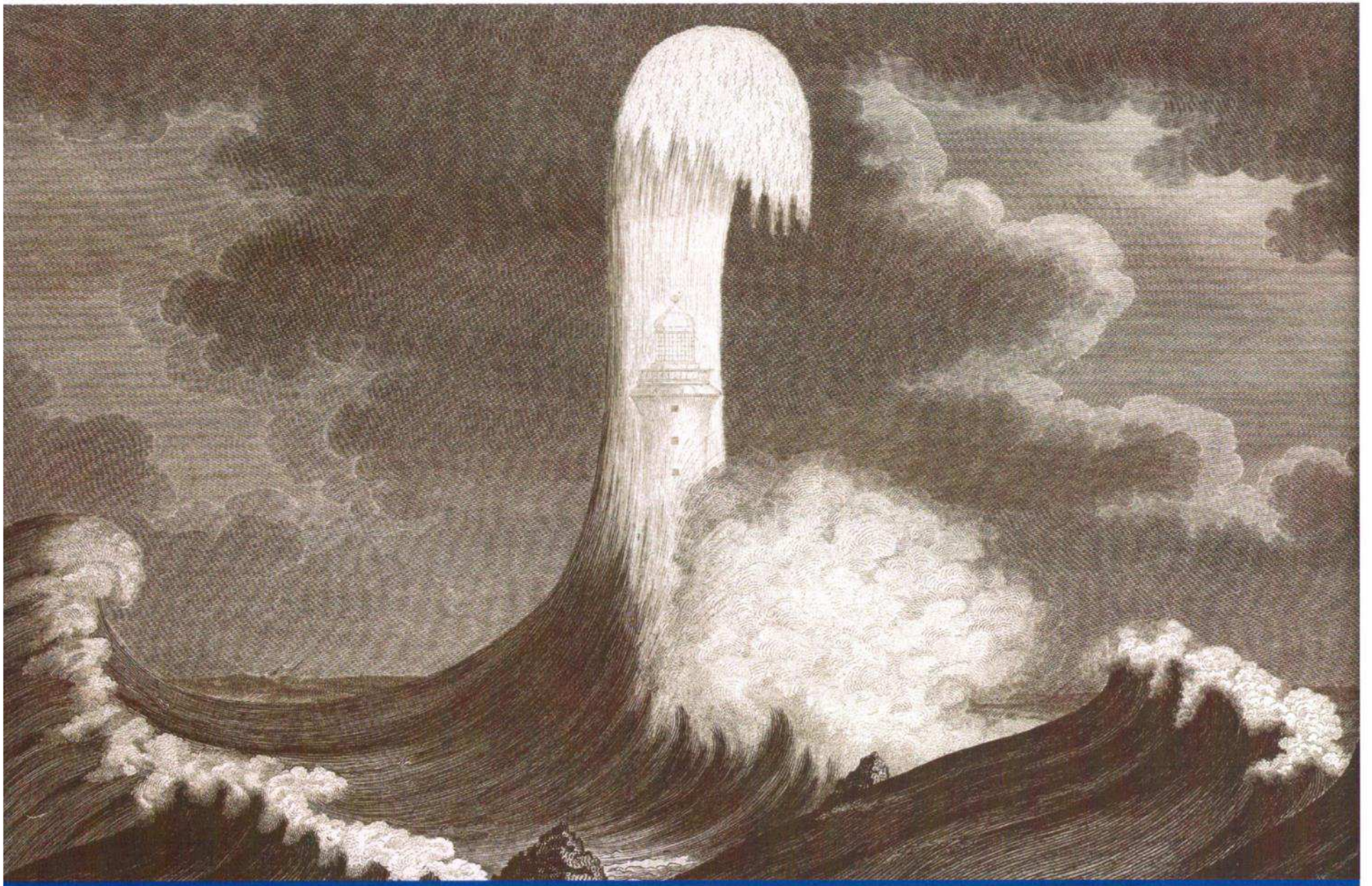


John Rennie FRS, FRSE

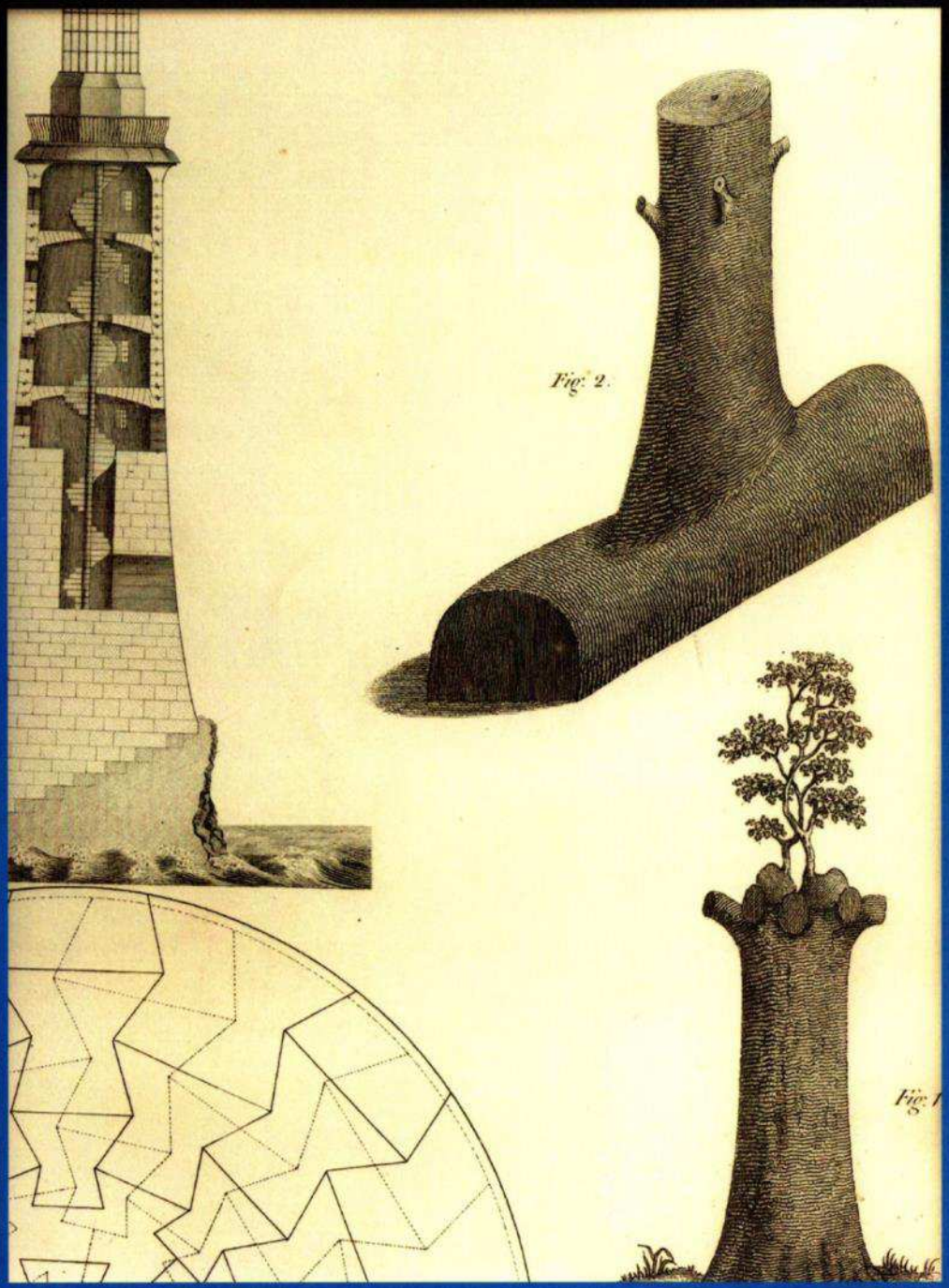


Robert Stevenson FRSE

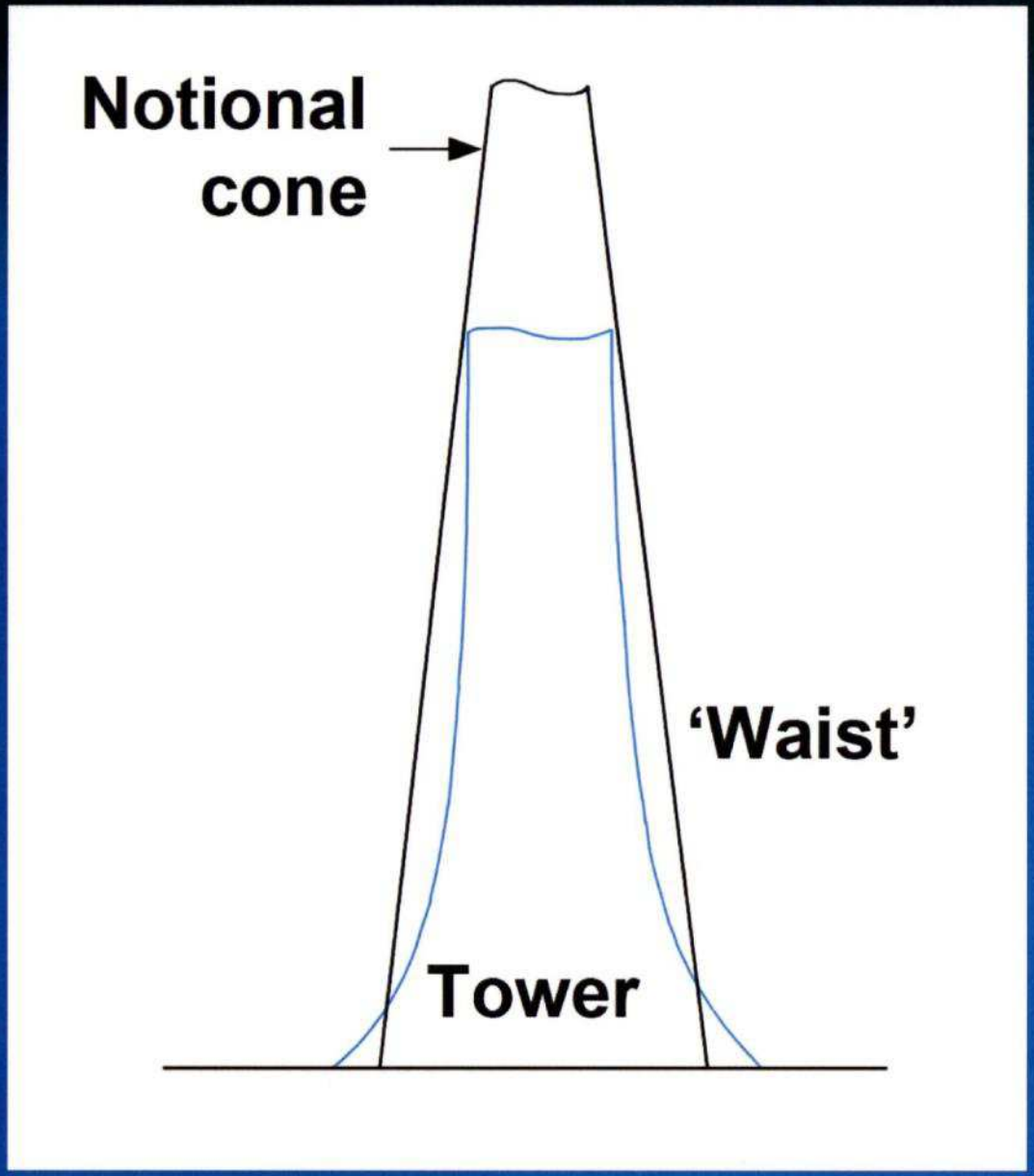
Chief Engineer John Rennie (1761-1821) and his assistant as resident engineer, and Engineer to the Northern Lighthouse Board from 1808-42, Robert Stevenson (1772-1850).



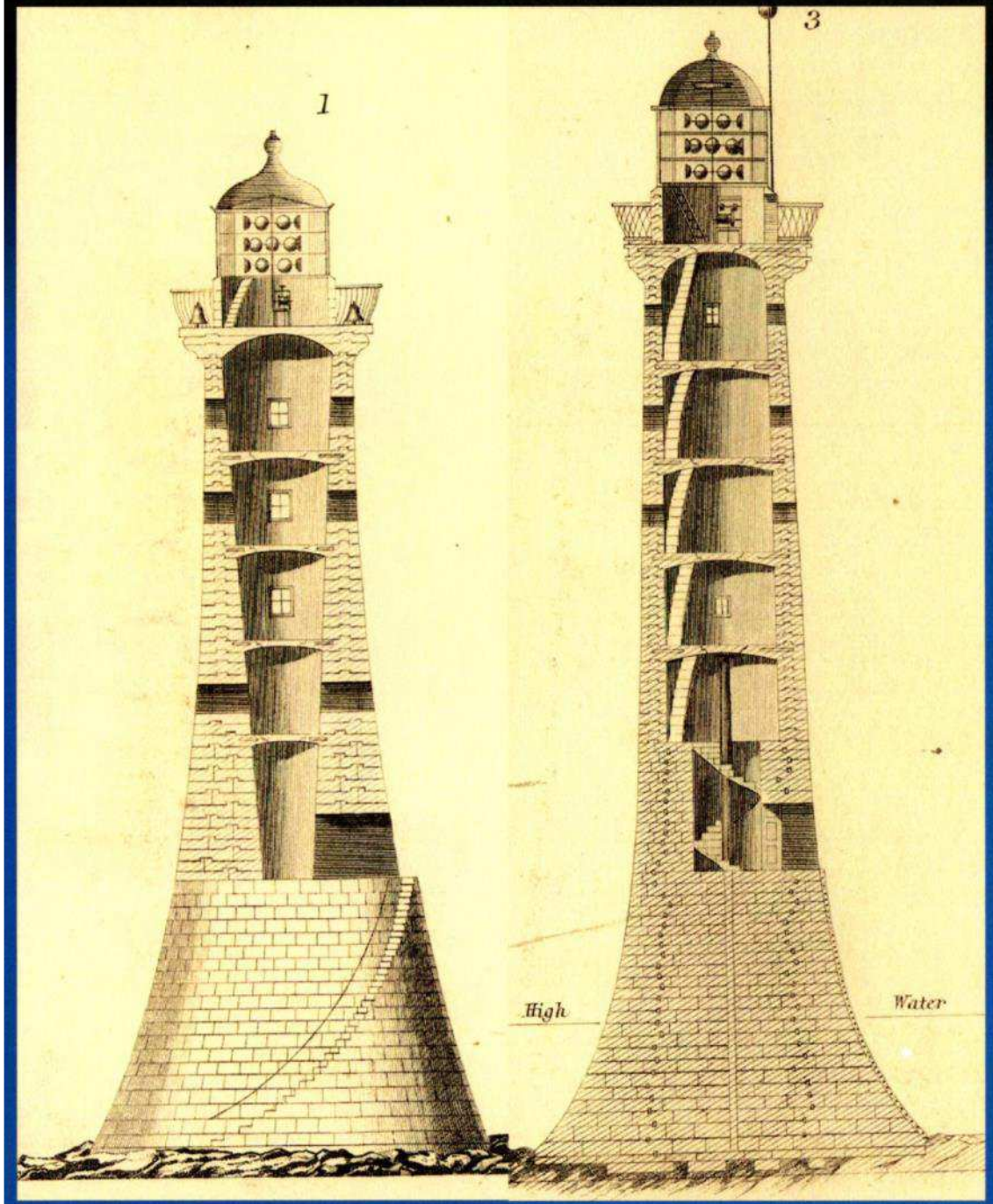
Eddystone Lighthouse 1757-59 (nr. Plymouth) in 1759 by the 'father' of civil engineering John Smeaton (1724-92)



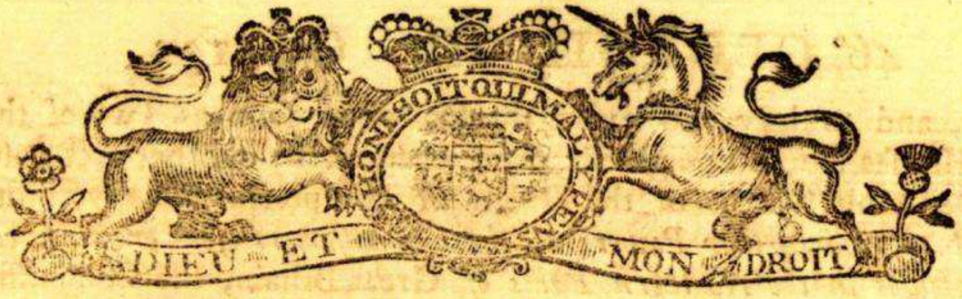
Smeaton promoted his design as structurally analogous to the trunk of an oak tree, which is arguable, but correctly propounded that the ultimate stability of a tower depends on the lowness of its centre of gravity – on the general notion of a cone – the horizontal forces on which decrease towards its top in a rapid ratio. He regarded dovetailed masonry as essential.



Smeaton's modified (in blue) conical design concept for Eddystone Lighthouse 1757



Stevenson's undovetailed design 1800-06 (left) and tower as-built under Rennie's overall direction as Chief Engineer. The implemented tower is 20% slenderer at 30ft height and the curvature at the rock is about 40° to the horizontal, features to dissipate wave force. Outside stair omitted. Thinner walls - more internal space. Lateral dovetailing adopted.



ANNO QUADRAGESIMO SEXTO

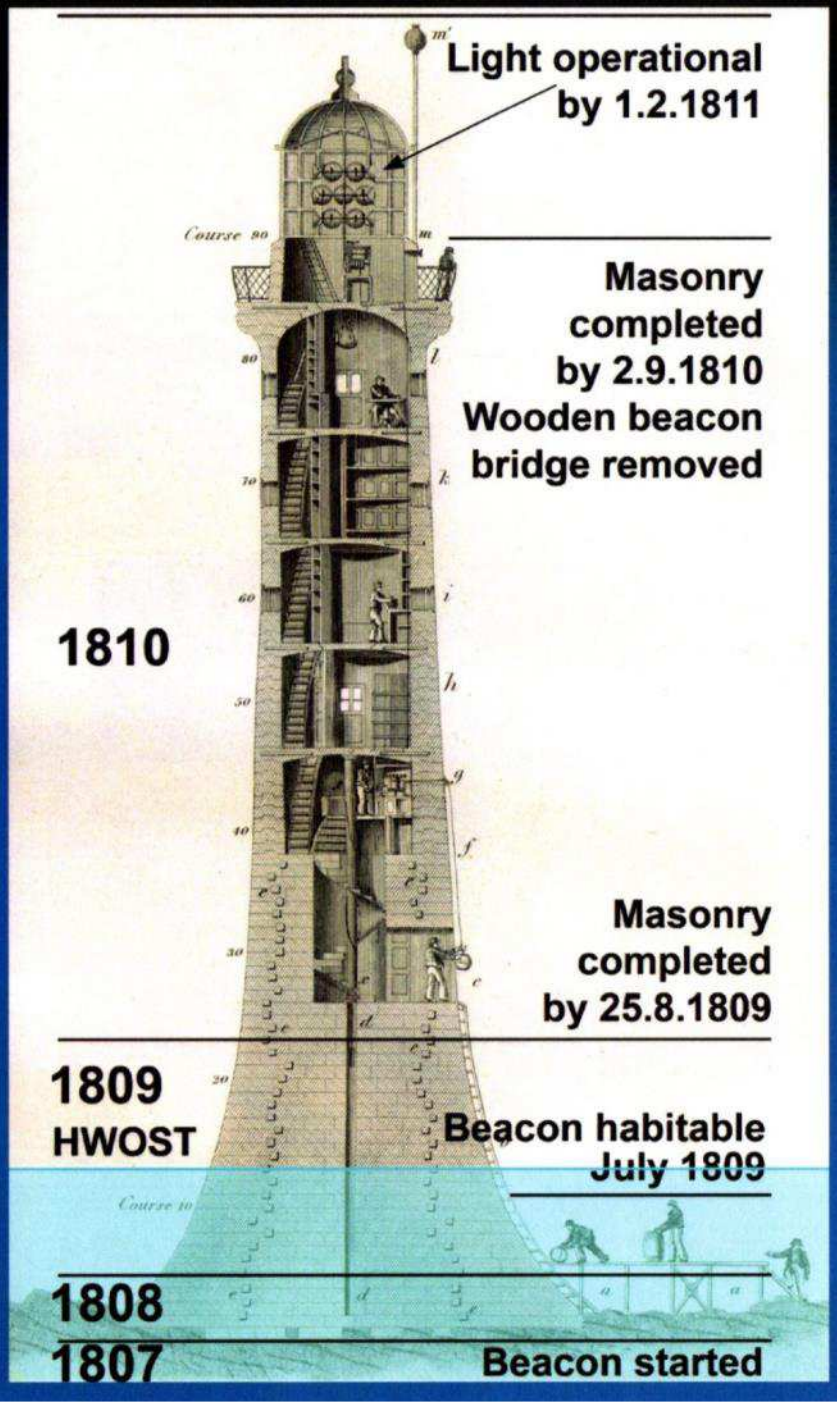
GEORGII III. REGIS.

C A P. CXXXII.

An Act for erecting a Light Houſe on the *Bell* or *Cape Rock*, on the Eaſtern Coaſt of *Scotland*, and for enabling the Commiſſioners of the Treaſury to advance a certain Sum of Money out of the Conſolidated Fund of *Great Britain*, towards that Purpoſe. [21ſt *July* 1806.]

WHEREAS by an Act, made in the Twenty-ſixth Year of His preſent Majeſty's Reign, intituled, *An Act for erecting certain* 26G.3. c.102

After an attempt for an Act in 1803 based on Stevenson's plan failed, an Act was obtained in 1806 with Rennie's backing - financed by shipping dues of 3d/ton.



Bell Rock Lighthouse - chronology of erection [on a base drawing of c1810 by Stevenson's clerk of works David Logan (1786-1839)] - railway bottom right. Note the considerable progress after the temporary beacon barrack alongside the lighthouse was habitable in July 1809

AN

ACCOUNT

OF THE

BELL ROCK LIGHT-HOUSE,

INCLUDING THE

DETAILS OF THE ERECTION AND PECULIAR STRUCTURE OF THAT EDIFICE.

TO WHICH IS PREFIXED A

HISTORICAL VIEW OF THE INSTITUTION AND PROGRESS

OF THE

NORTHERN LIGHT-HOUSES.

ILLUSTRATED WITH TWENTY-THREE ENGRAVINGS.

DRAWN UP BY DESIRE OF

THE COMMISSIONERS OF THE NORTHERN LIGHT-HOUSES,

BY

ROBERT STEVENSON,

CIVIL ENGINEER;

FELLOW OF THE ROYAL SOCIETY OF EDINBURGH;

MEMBER OF THE SOCIETY OF SCOTISH ANTIQUARIES, OF THE WERNERIAN NATURAL HISTORY SOCIETY, AND OF THE GEOLOGICAL SOCIETY OF

ENGINEER TO THE NORTHERN LIGHT-HOUSE BOARD,

OF ROYAL BOROUGHS OF SCOTL

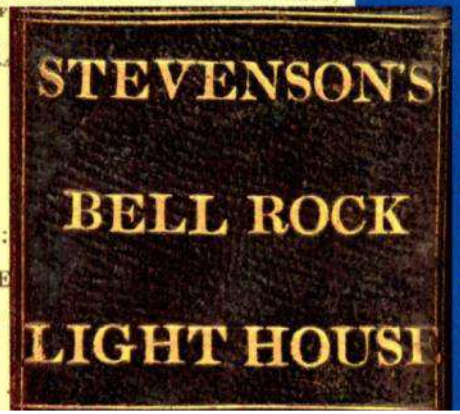
EDINBURGH:

PRINTED FOR ARCHIBALD CONSTABLE

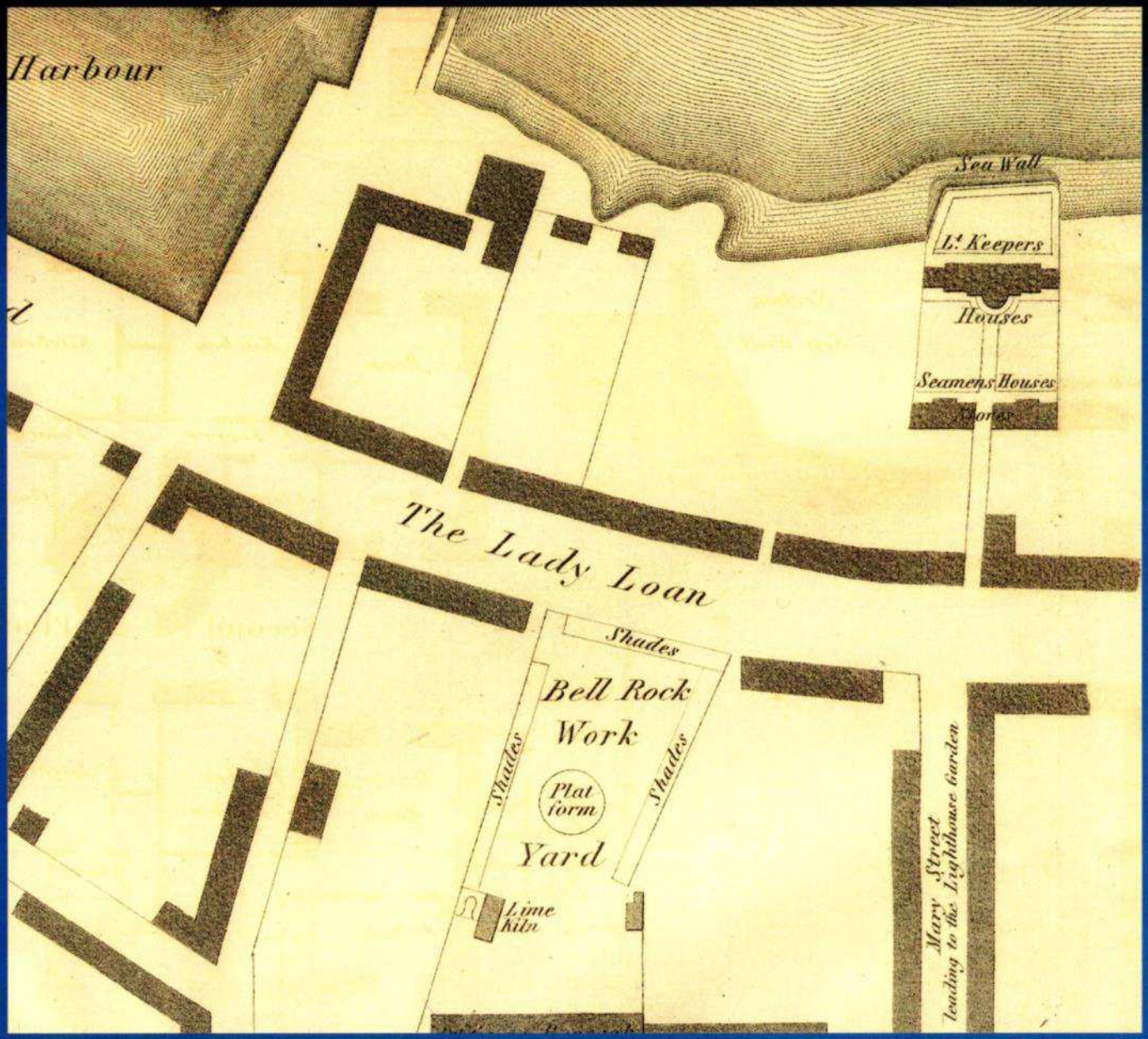
HURST, ROBINSON & CO. 90. CHEAPSIDE; AND JOSIAH

LONDON.

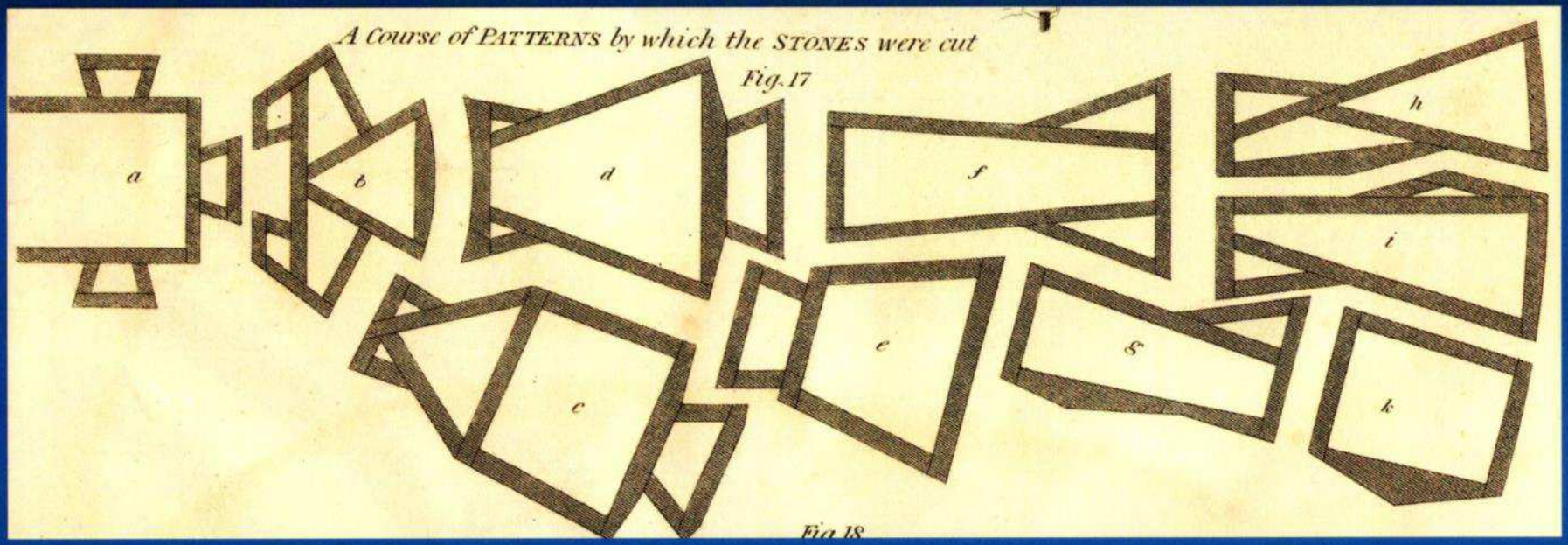
1824.



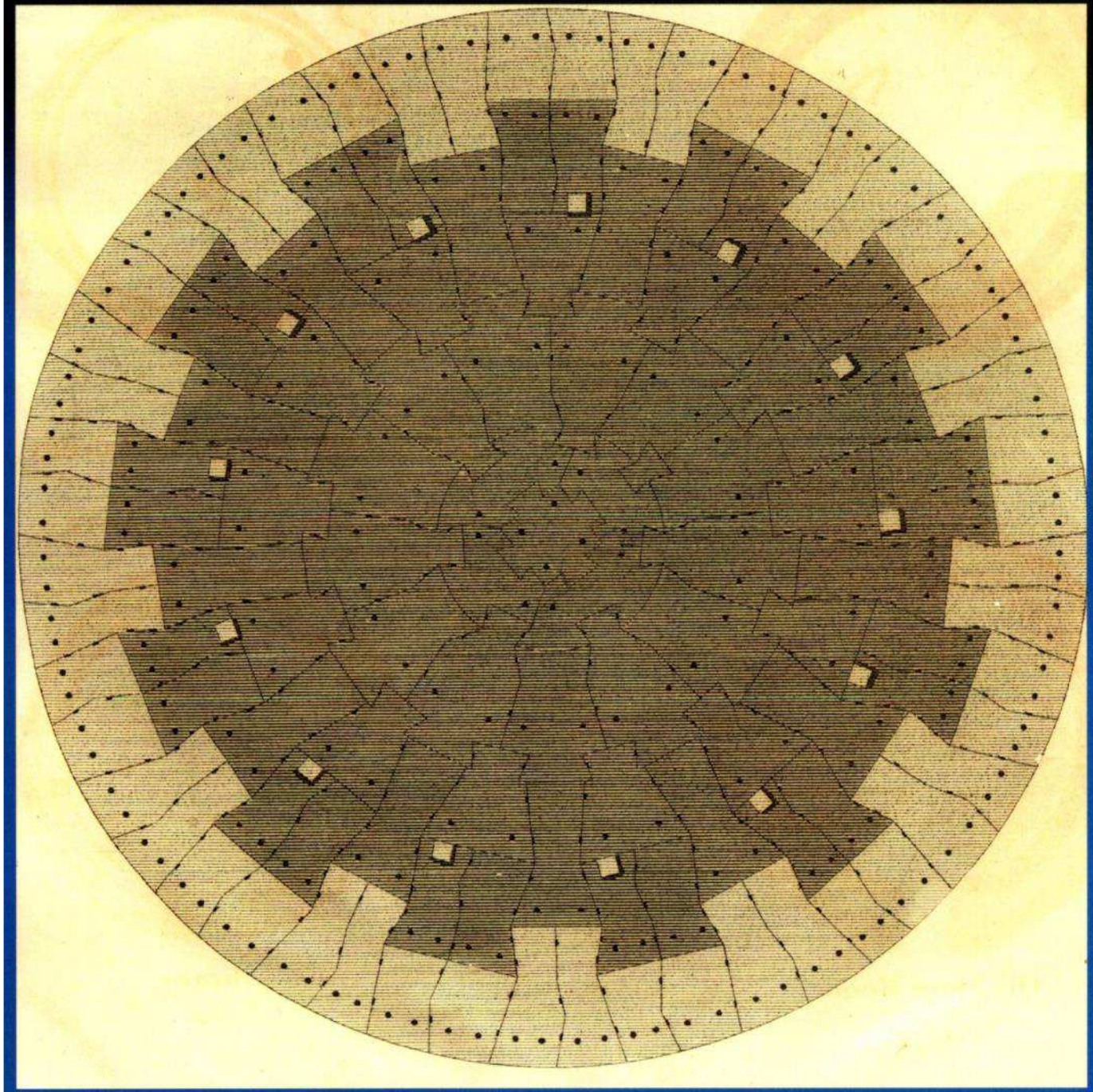
Stevenson's account of building the lighthouse is a classic of civil engineering modelled on Smeaton's Eddystone Lighthouse book 1791, which it complements in terms of lighthouse engineering development. It is a masterpiece of engineering description, but short on the 'strength of materials' design aspect and credit for his Chief Engineer's contribution! The book enhanced Stevenson's reputation.



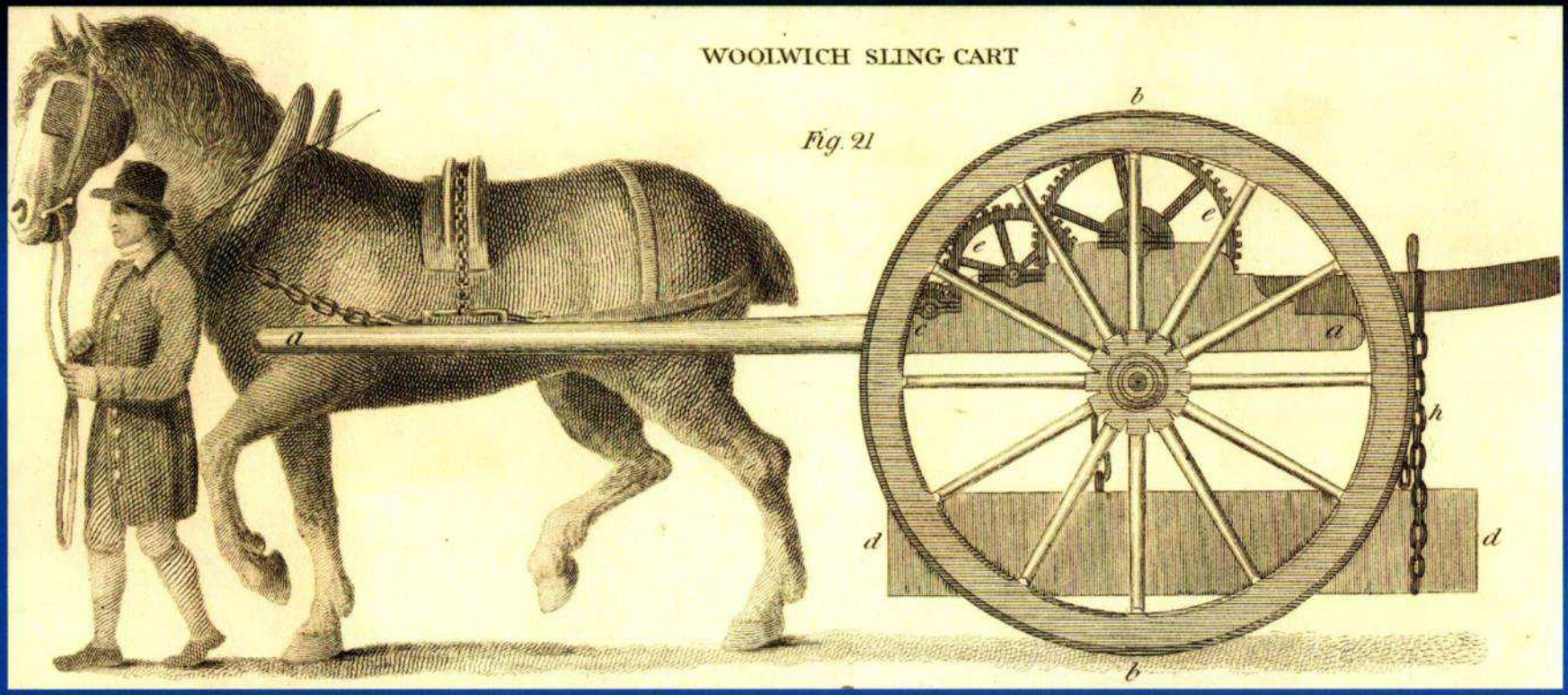
Bell Rock workyard at Arbroath. The circular platform carried each course of stone before shipping to the Rock. The first entire course assembled June 1808.



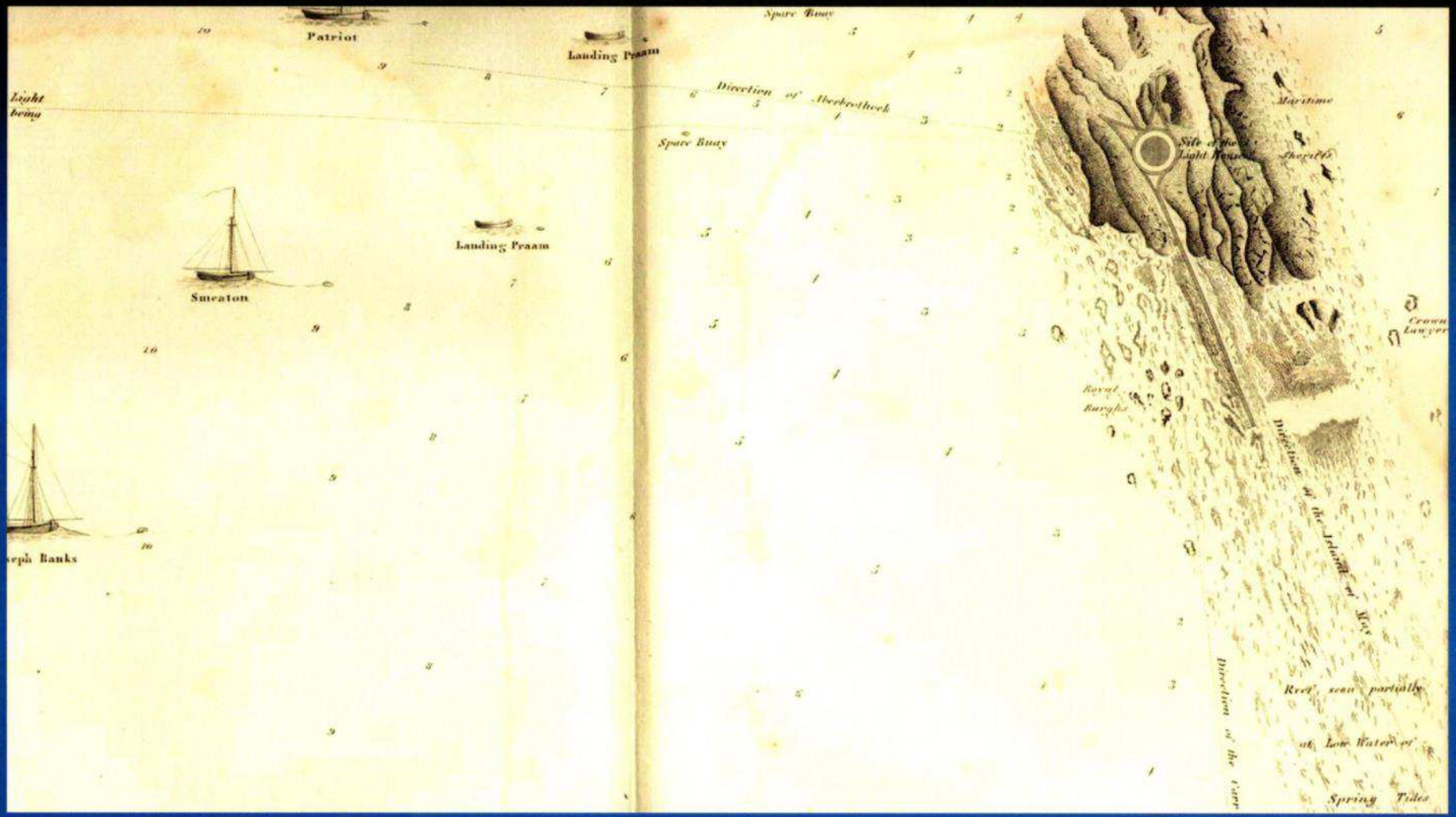
Wooden patterns used at Arbroath to enable each stone in a course to be dressed to the right size.



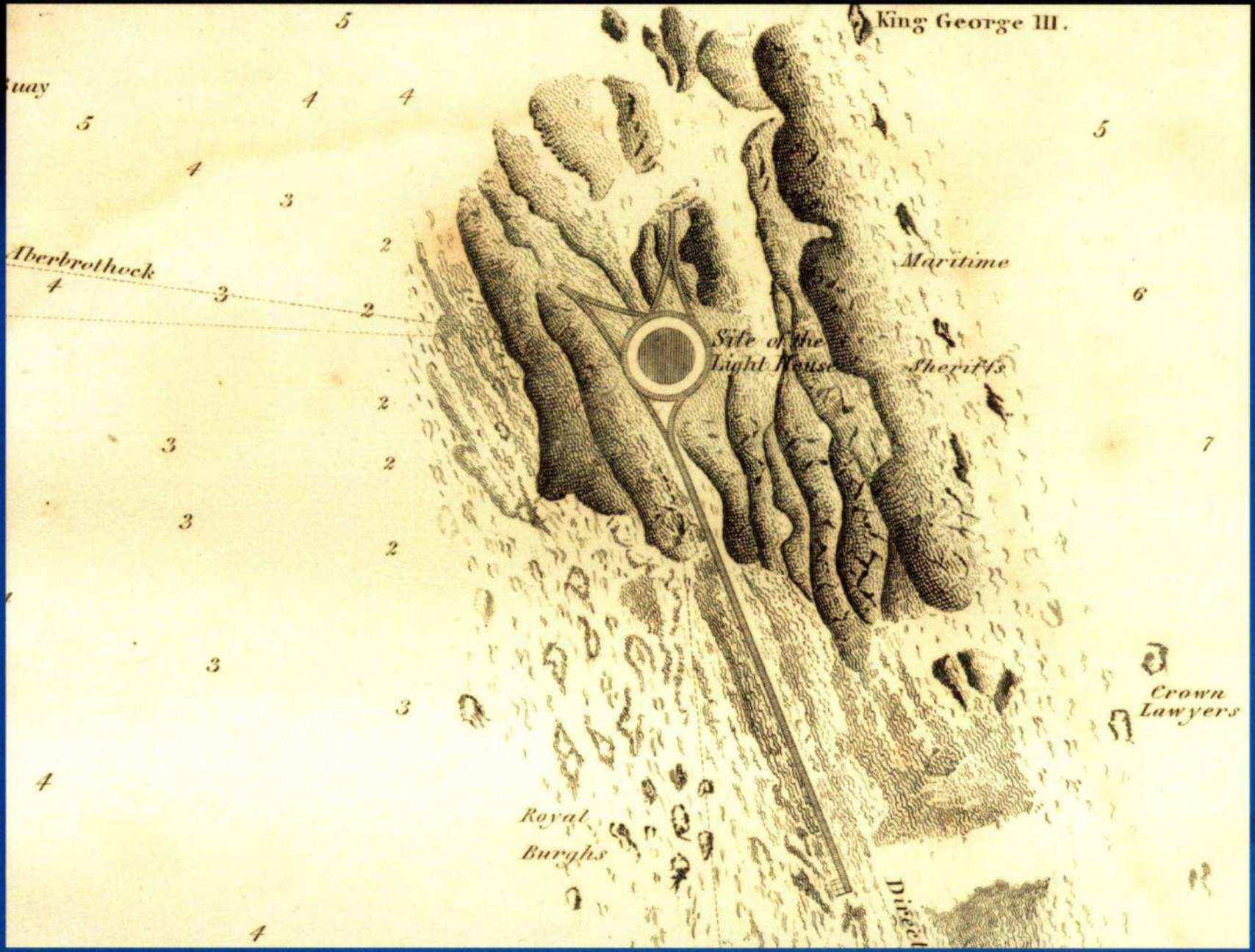
First entire course [1ftx42ft dia. 104 tons] 123 stones from 11 patterns. Outer stones Aberdeen granite, inner – sandstone from Mylnefield quarry near Dundee. Note: 246 oak tre-nails,13 joggles and 378 pairs of wedges used. Mortar (grout) - 1:1:1 parts sand, Pozzalano and Aberthaw lime.



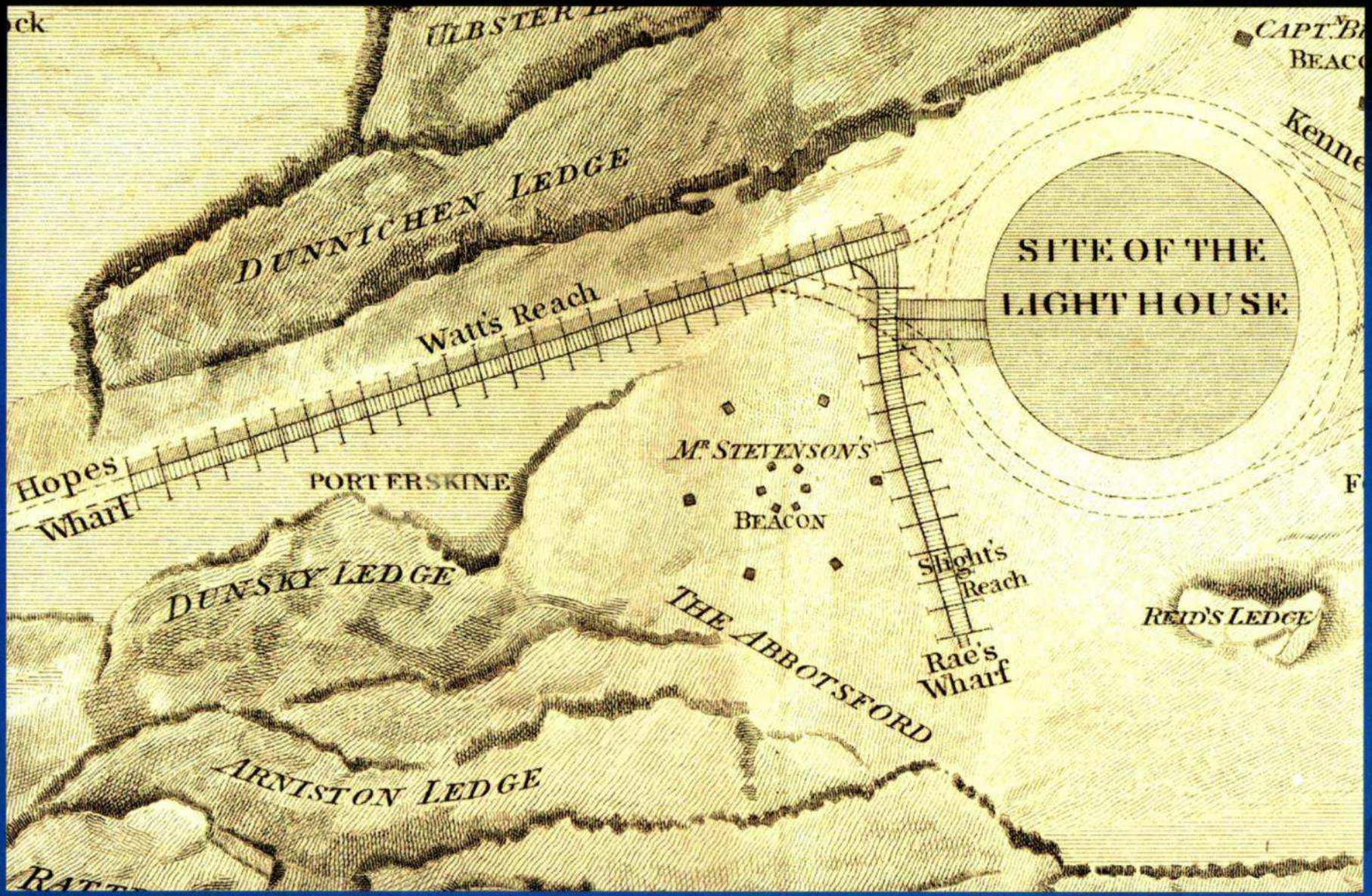
James Craw with ‘Bassie’ hauling stone in and around the Arbroath workyard and to and from the harbour



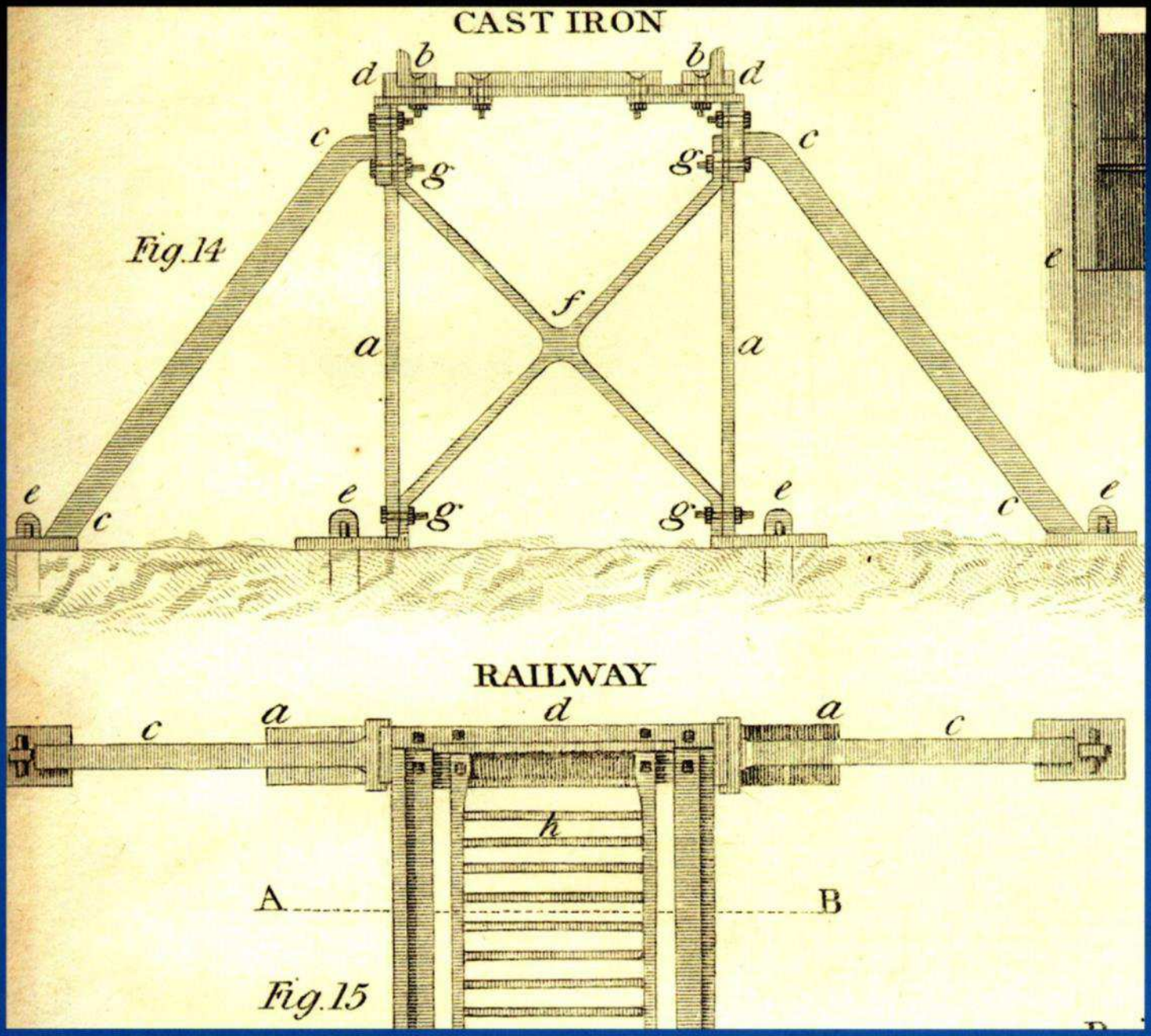
Shipping: Sir Joseph Banks – Smeaton – Patriot and praam boats



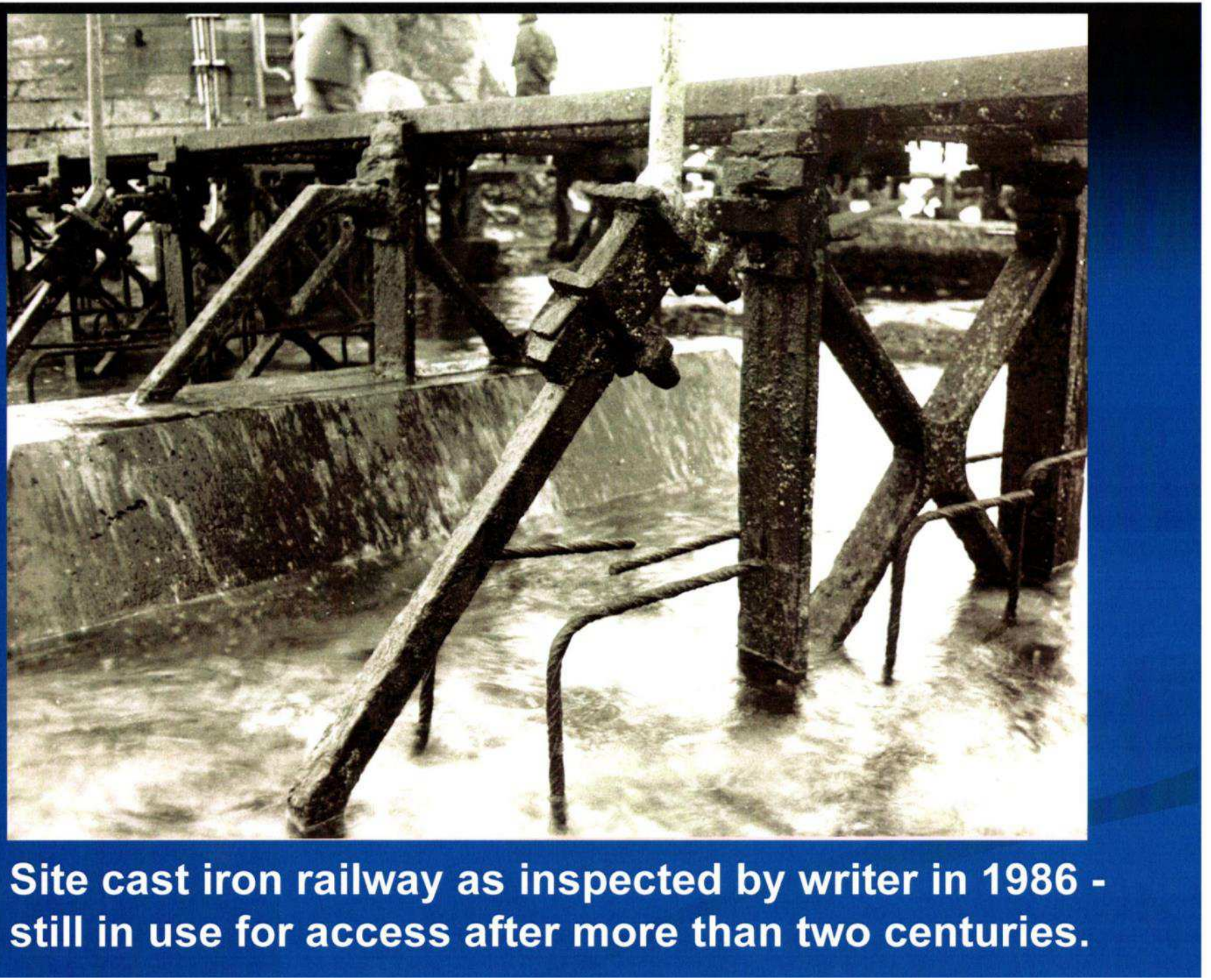
Proposed railway from landing places to lighthouse site



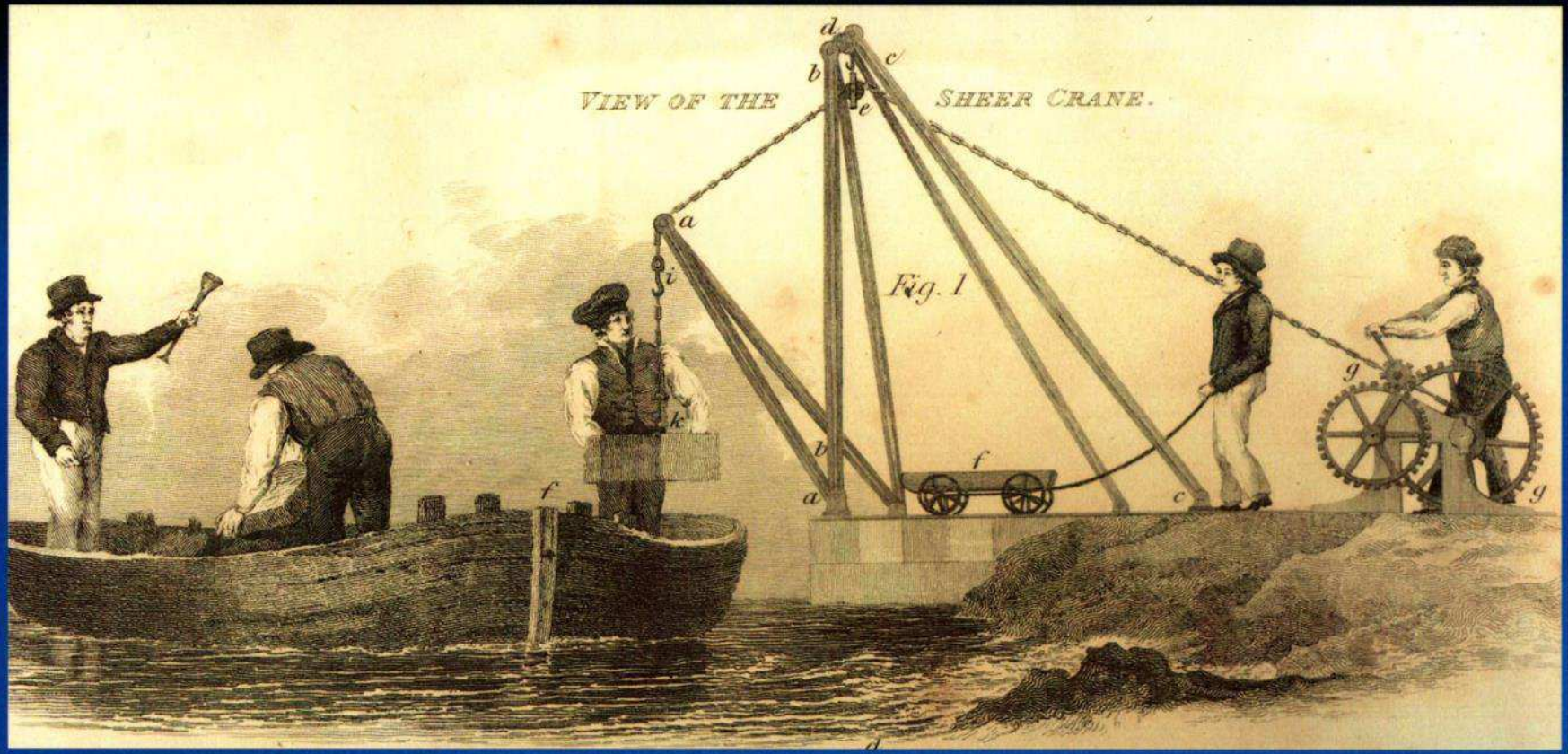
Plan showing railway and temporary beacon site



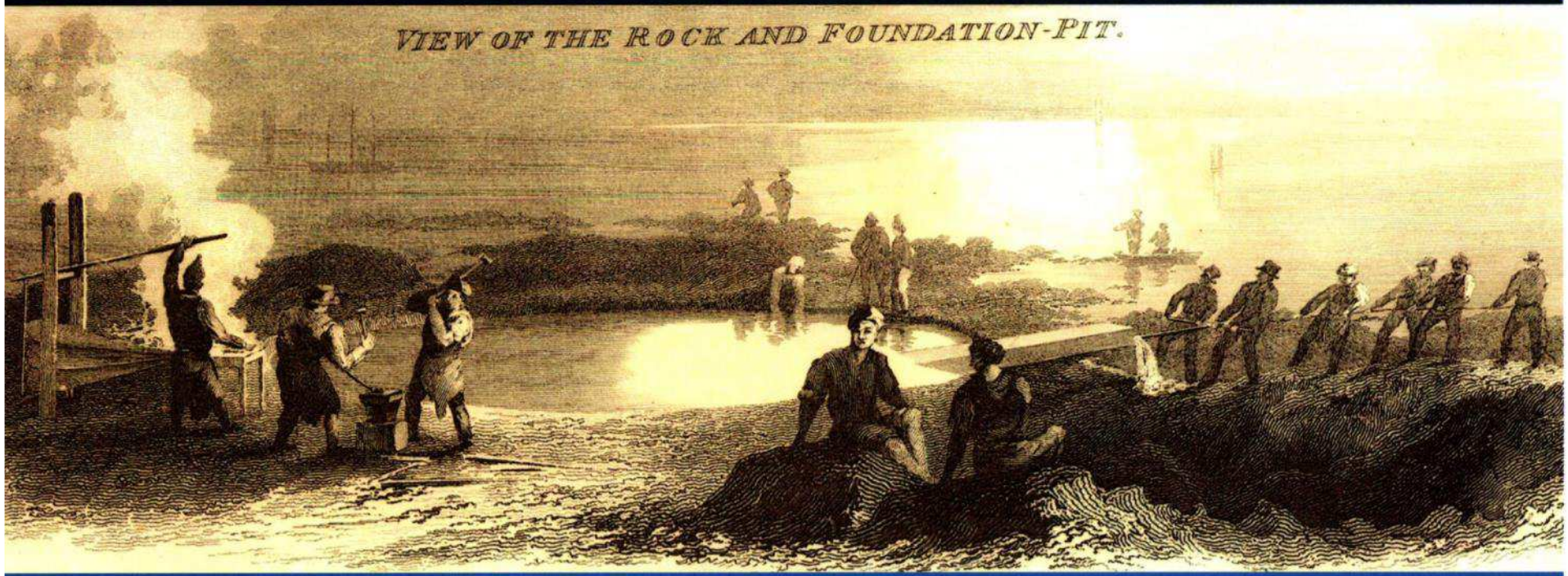
Railway over uneven rock surface – designed by Francis Watt



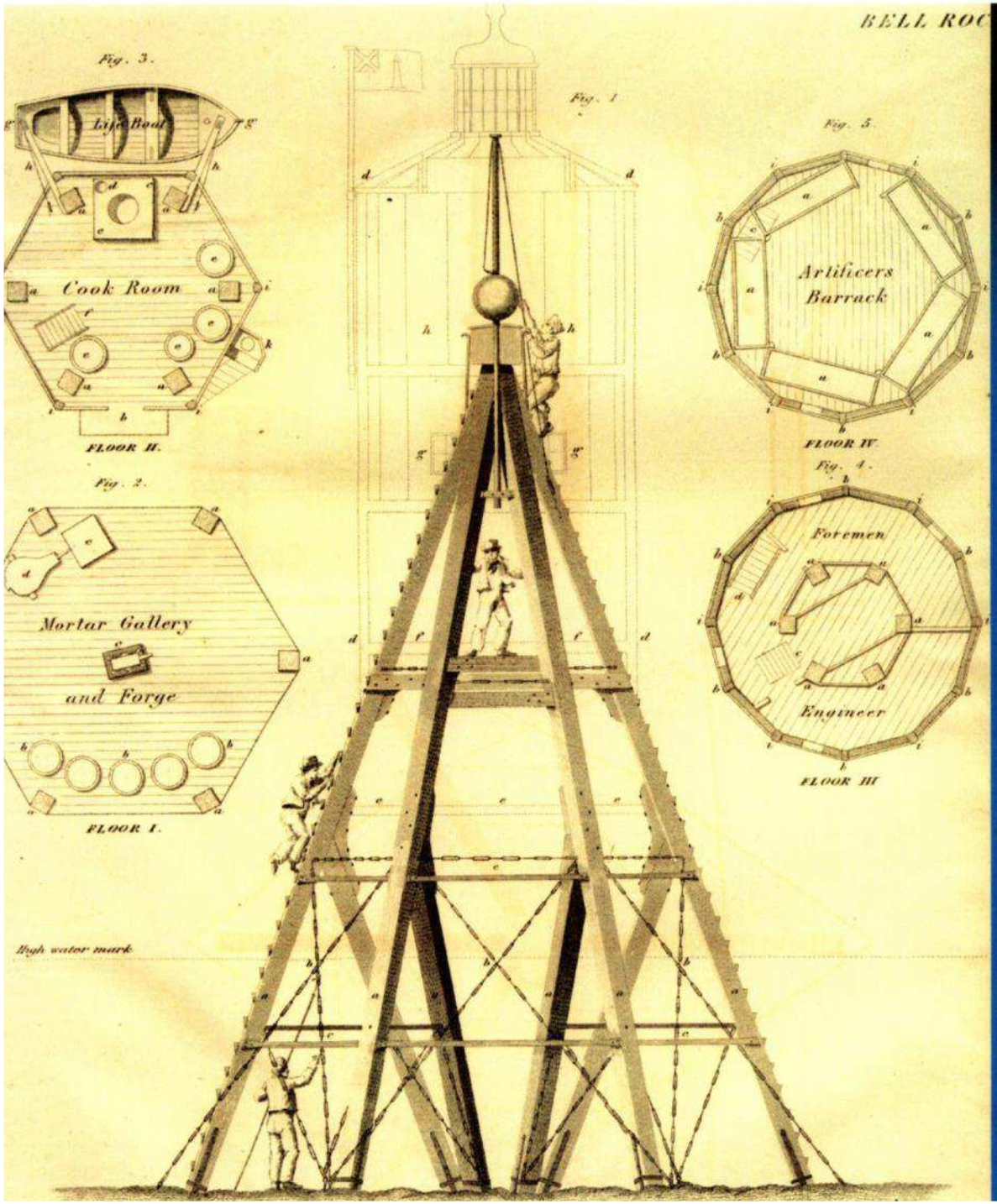
Site cast iron railway as inspected by writer in 1986 - still in use for access after more than two centuries.



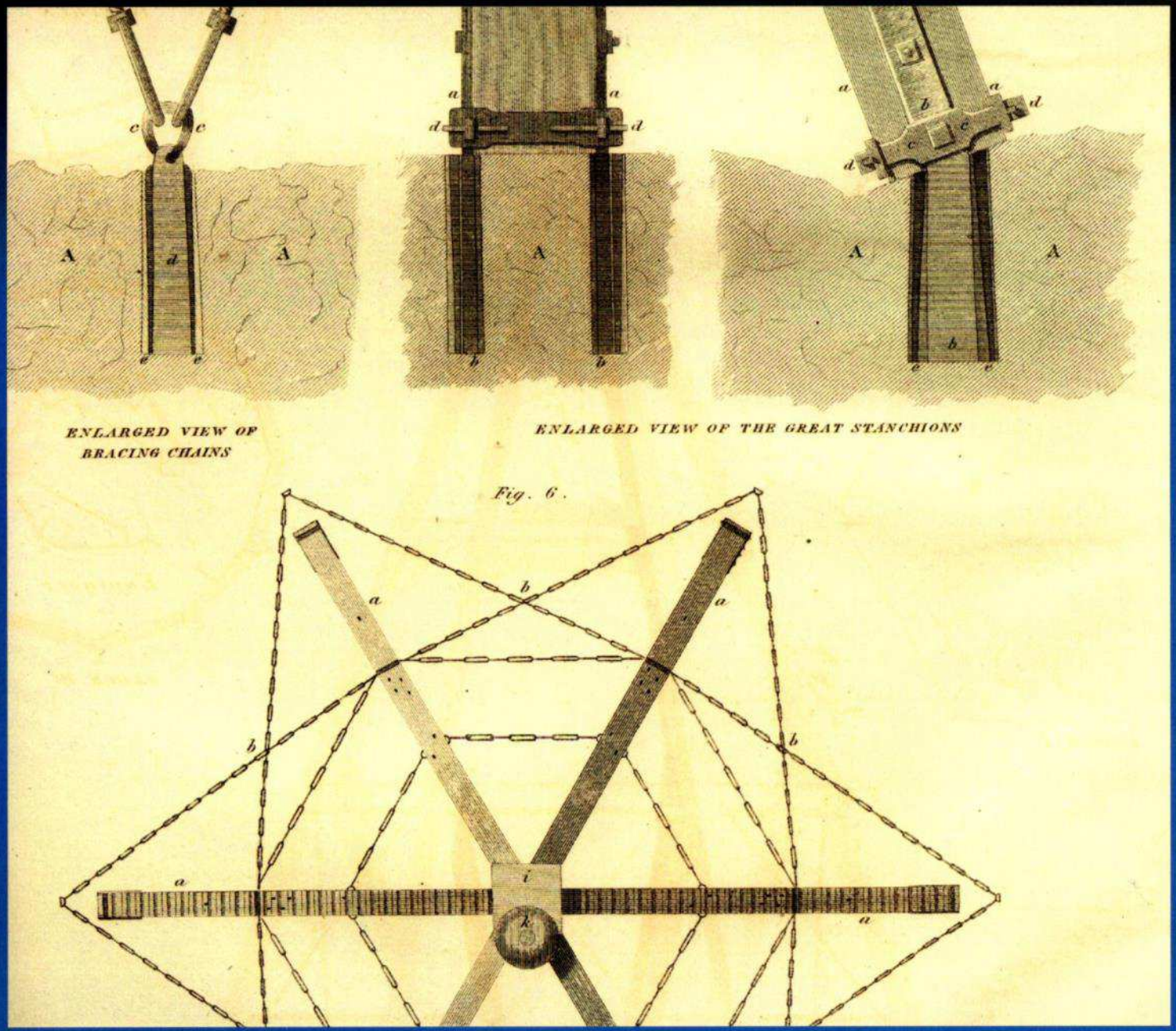
Transferring stone from praam boat to waggon on plate railway by sheer crane 1808-1810



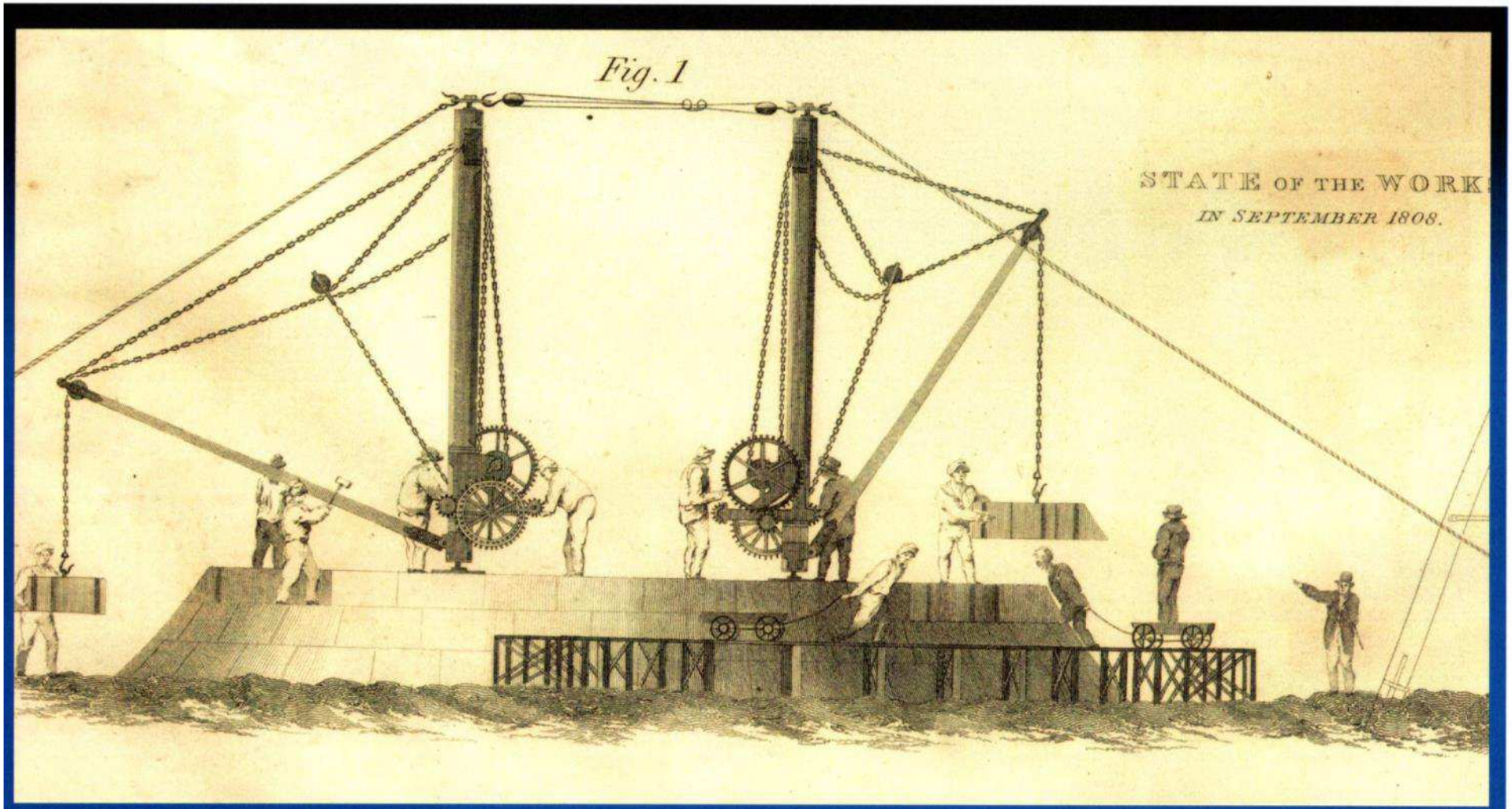
View of foundation pit in 1807 being de-watered by six men and ironwork being forged to anchor the temporary beacon legs to rock. After about 2 hours work the tide began to rise and inundate the forge.



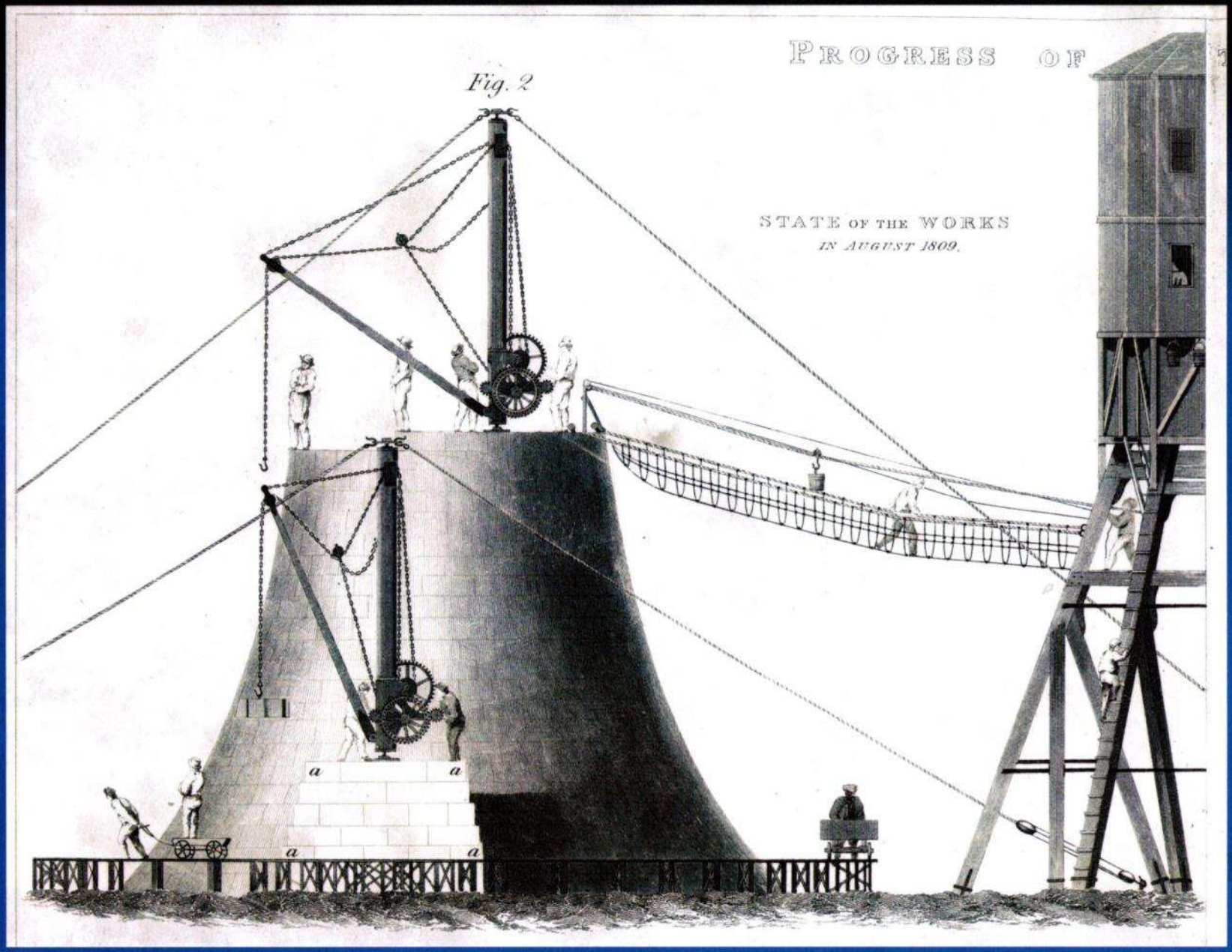
Temporary beacon to facilitate work October 1807 – Watt's design. Note: bracing chains and bars; four levels – mortar gallery, cook room, engineer and foremens and workmens rooms. *Inhabited by Stevenson and up to 28 men* **from July 1809 to Sept. 1810]**



Details of beacon fixing and bracing. Stanchions 50 ft long x 1 ft square.

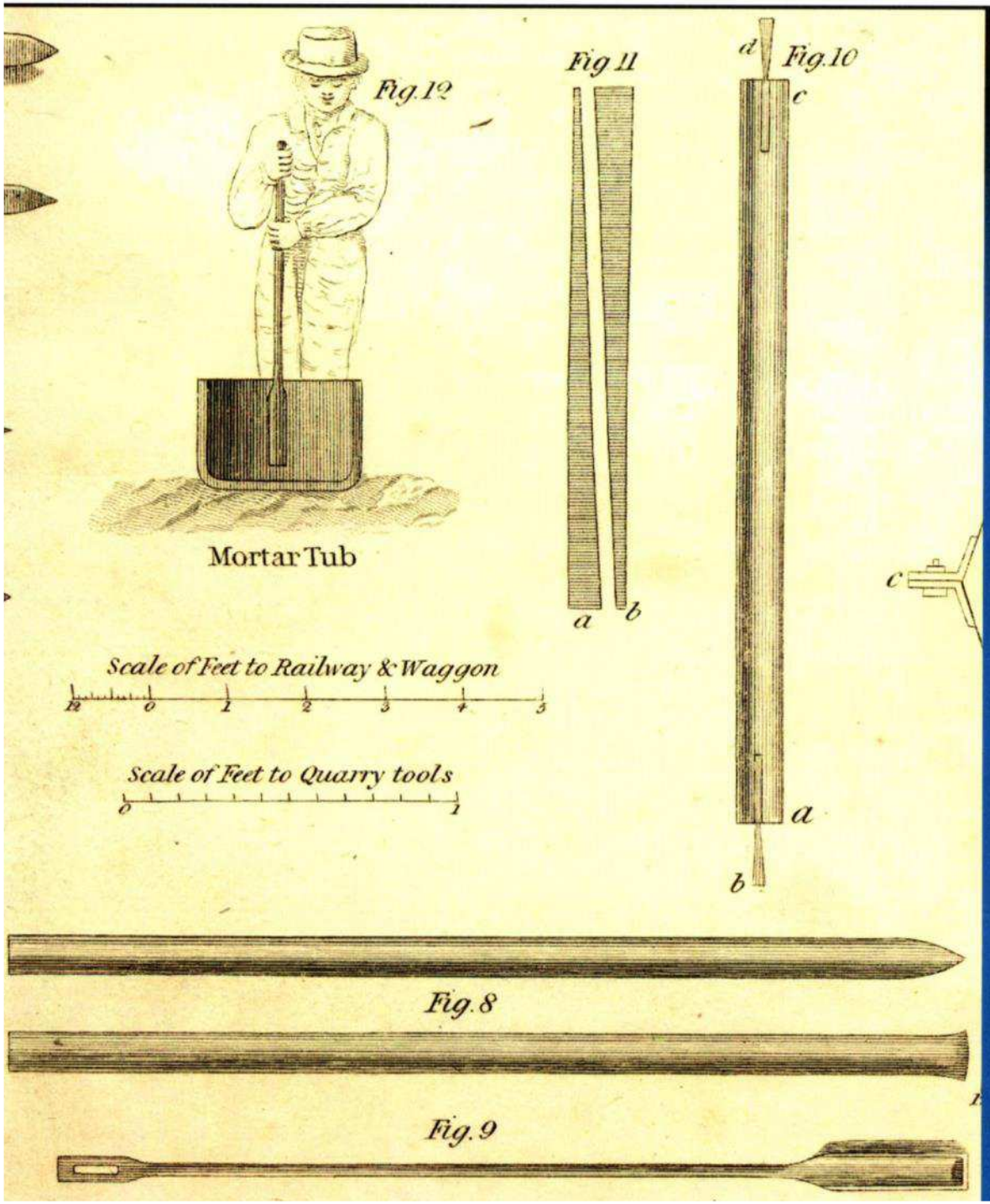


Operations at Bell Rock in September 1808 – innovative jib cranes with Spanish windlass effect.



State of the works August 1809 – masonry 60% complete.

The base of the lighthouse as inspected by the writer in 1986



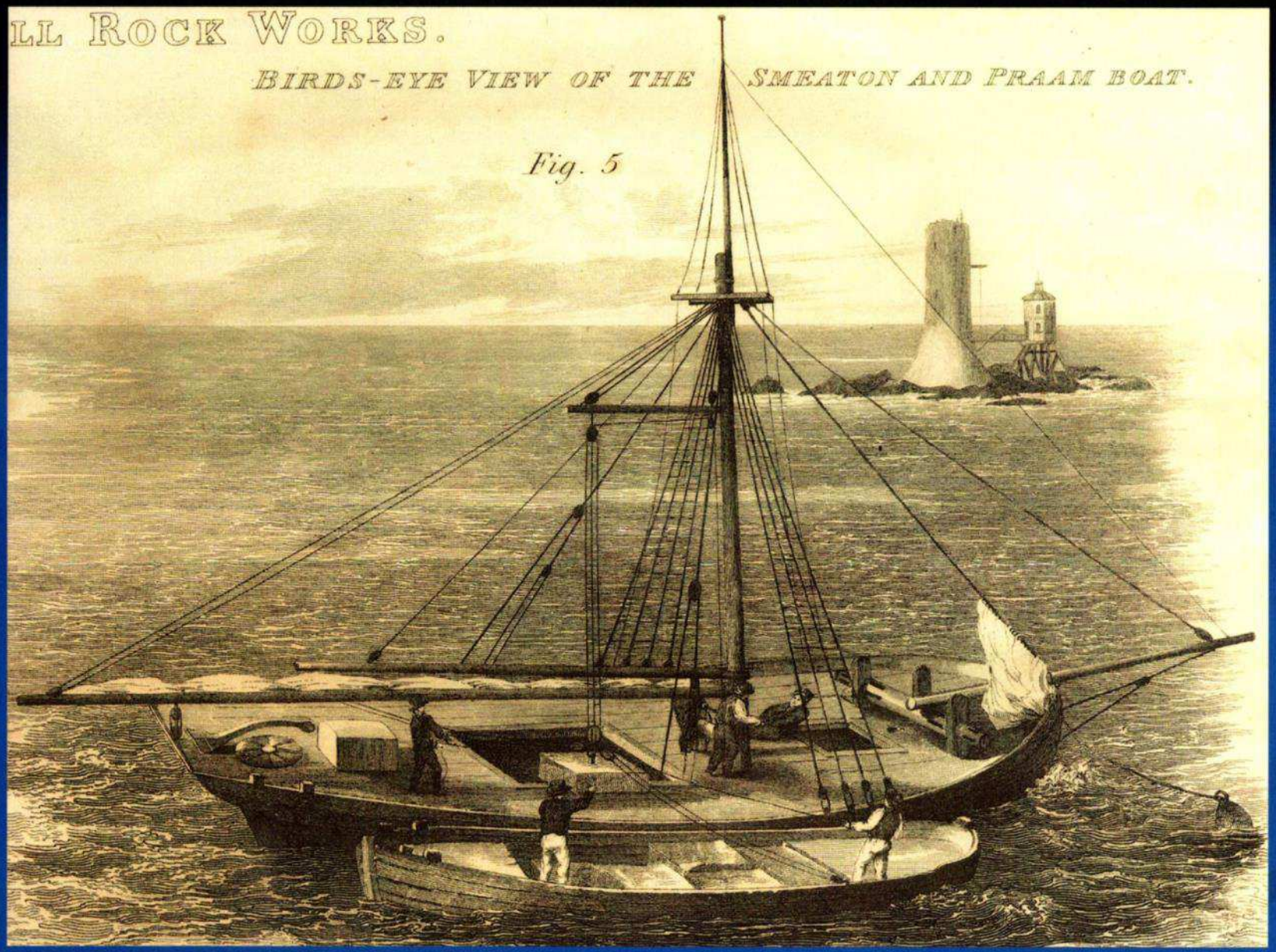
Boring tools (1½" diameter)

Hole scraper

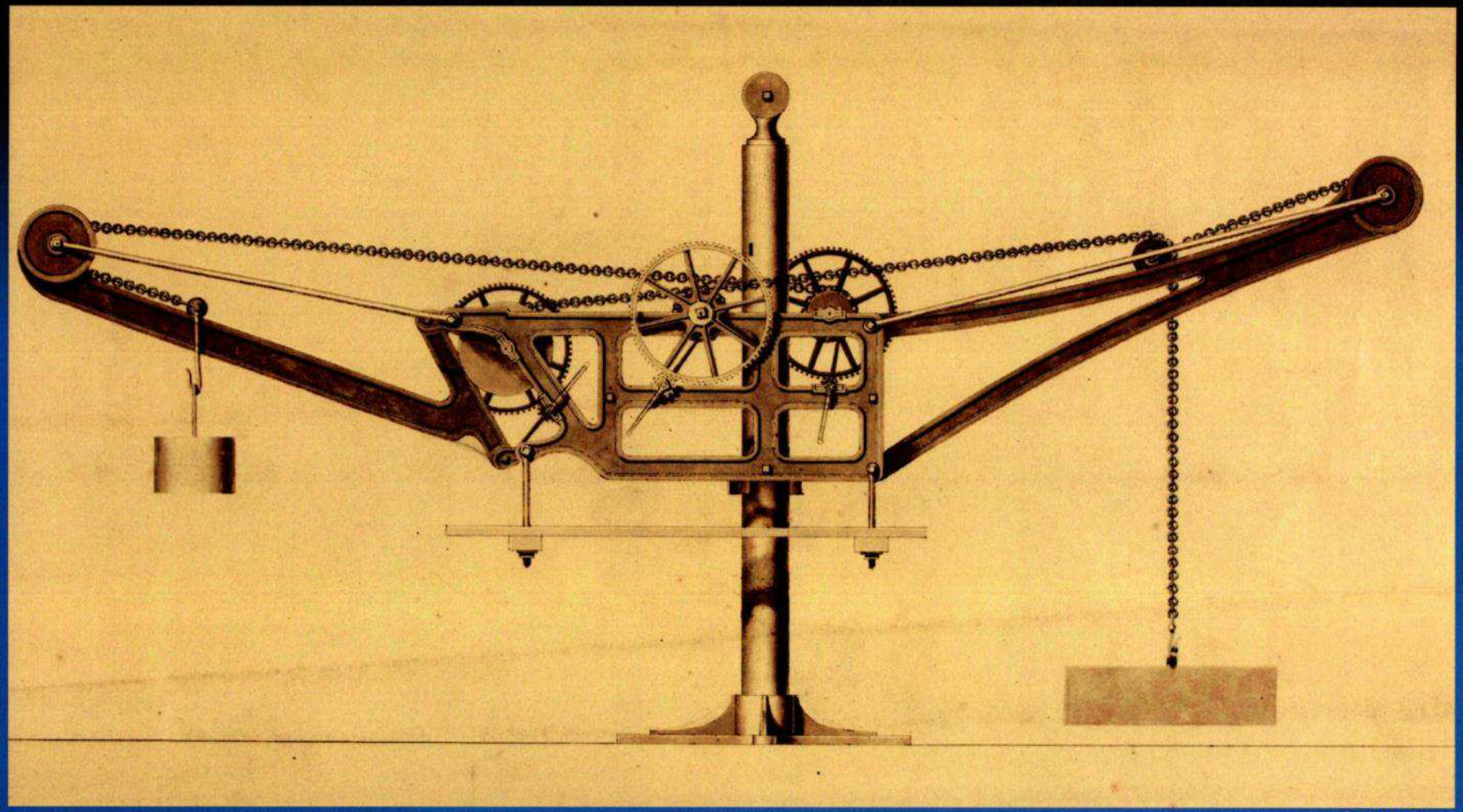
Oak trenails (to be inserted 6" into course below)

Oak wedges (to be used in pairs)

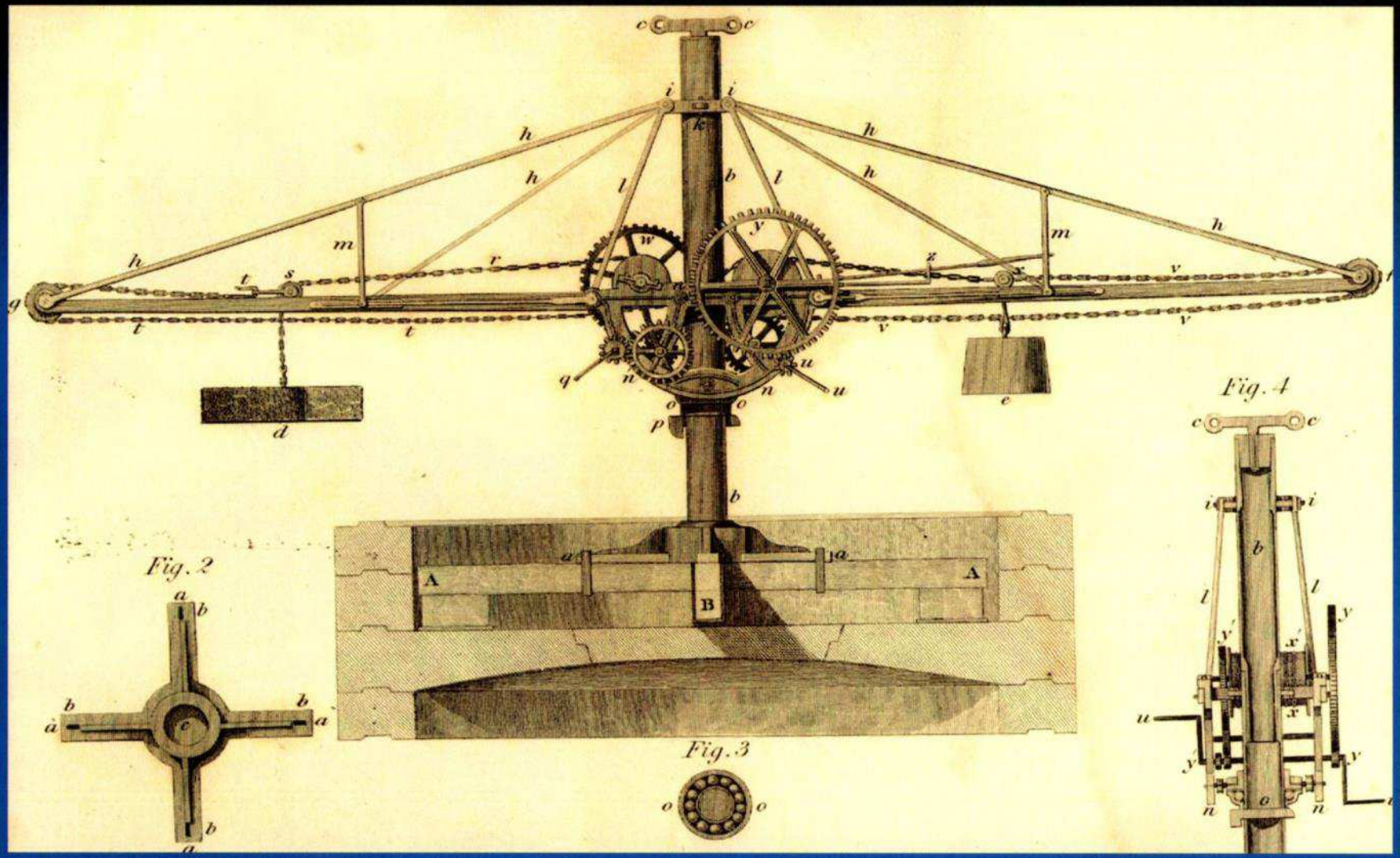
Mortar tub.



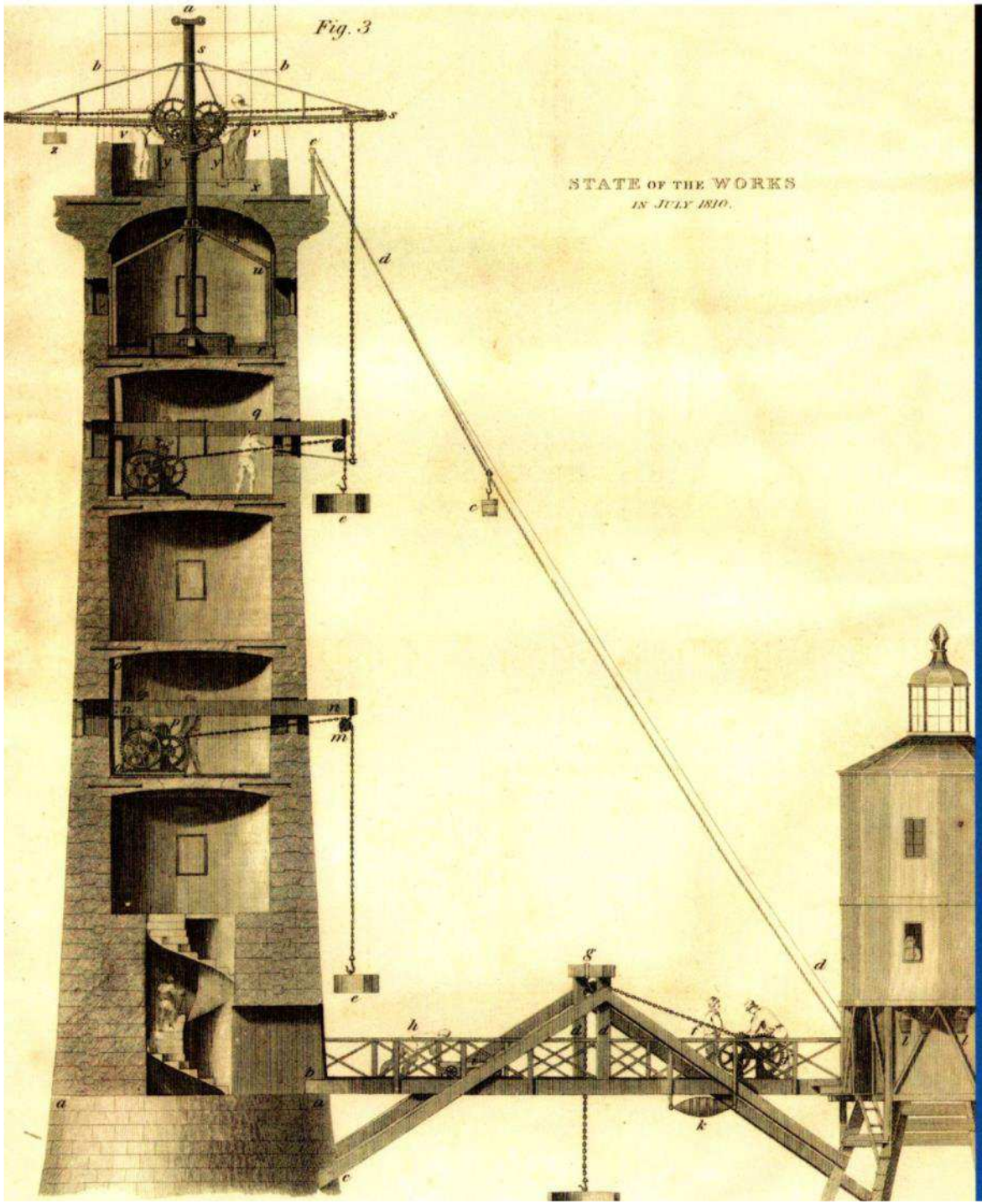
Off-loading stone from the Smeaton into a praam June 1810



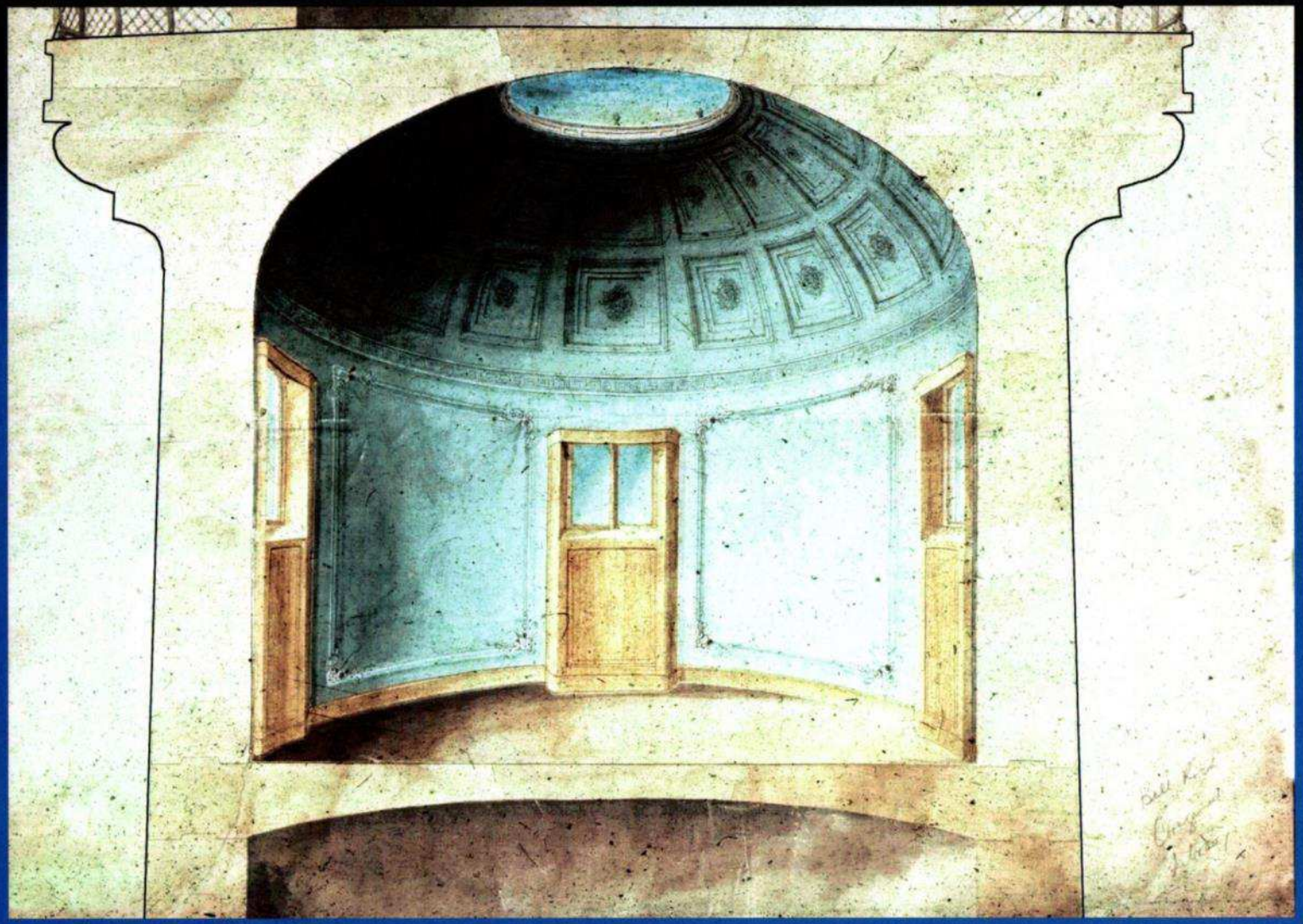
Bell Rock Lighthouse – iron balance crane used to erect the tower. Designed under Stevenson's direction by Francis Watt, drawn by David Logan – The world's first iron tower crane.



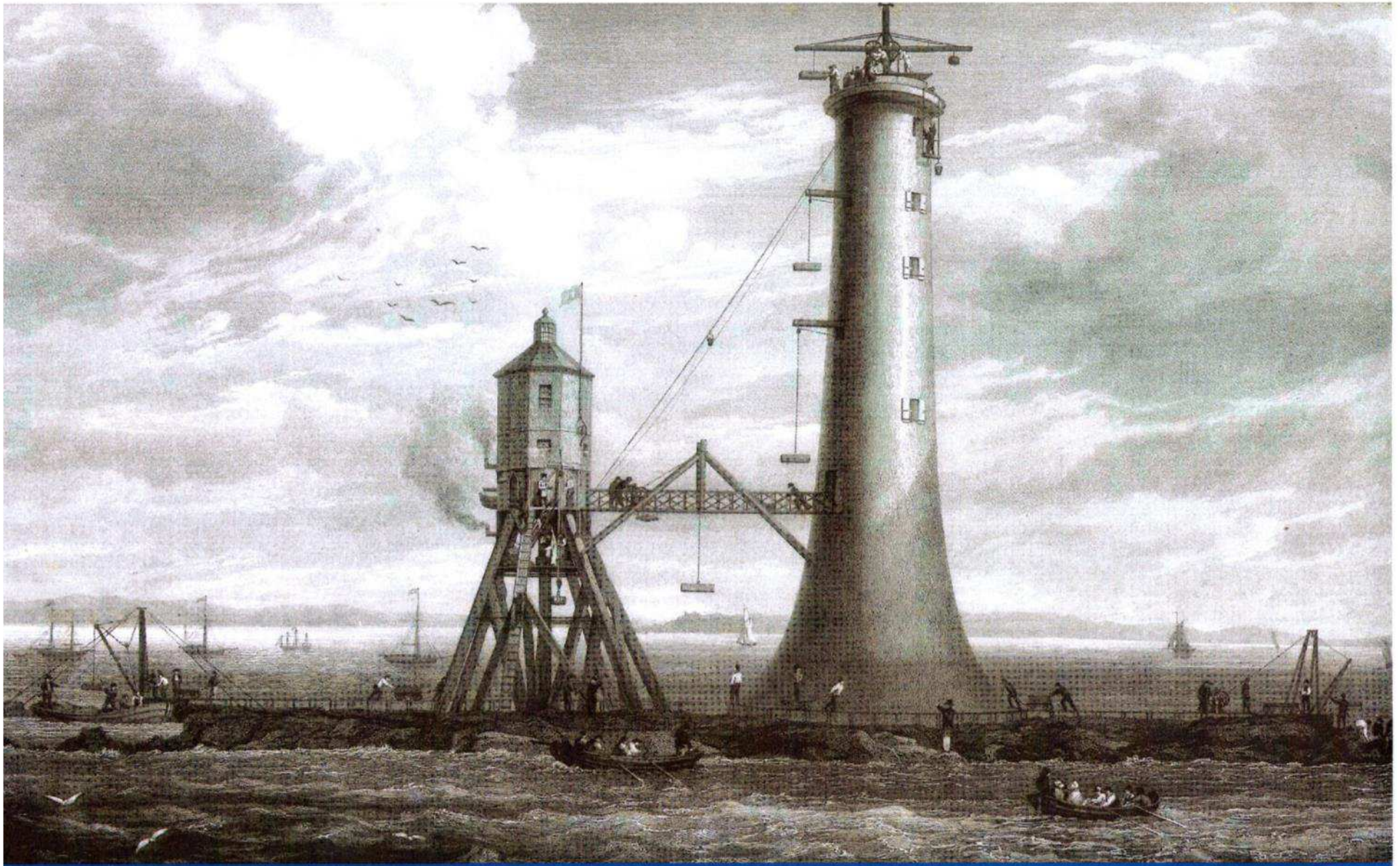
Variant of Watt's balance crane used at Carr Rock 1817 with horizontal travel beam for weight and stone (James Slight?)



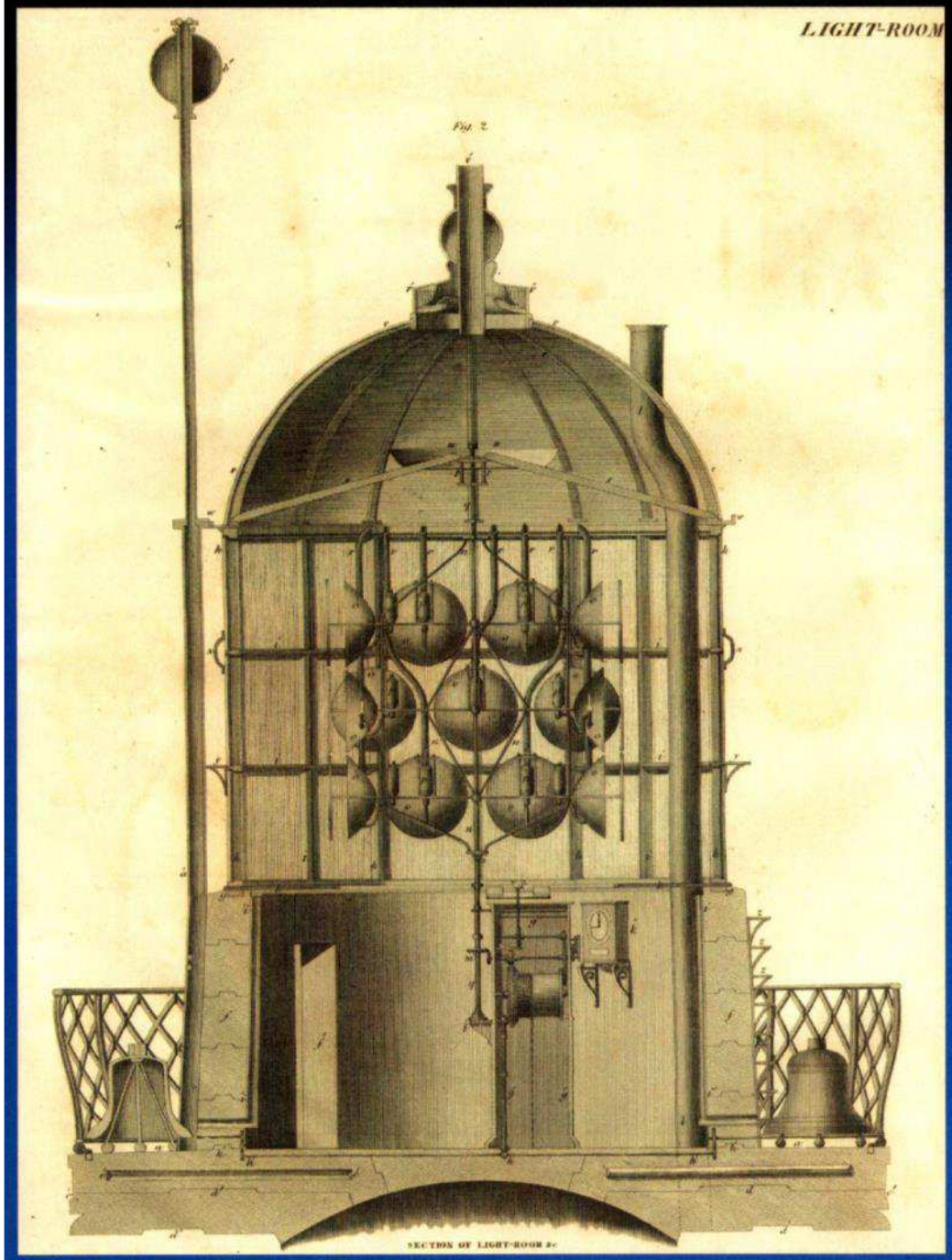
Operations at Bell Rock lighthouse in July 1810.
Note shaft of tower crane passing through light-room floor being used with the 3-winch arrangement to get the stones up 100+ ft from the railway to the light-room wall – note also the bucket in transit from the beacon mortar gallery to tower top.



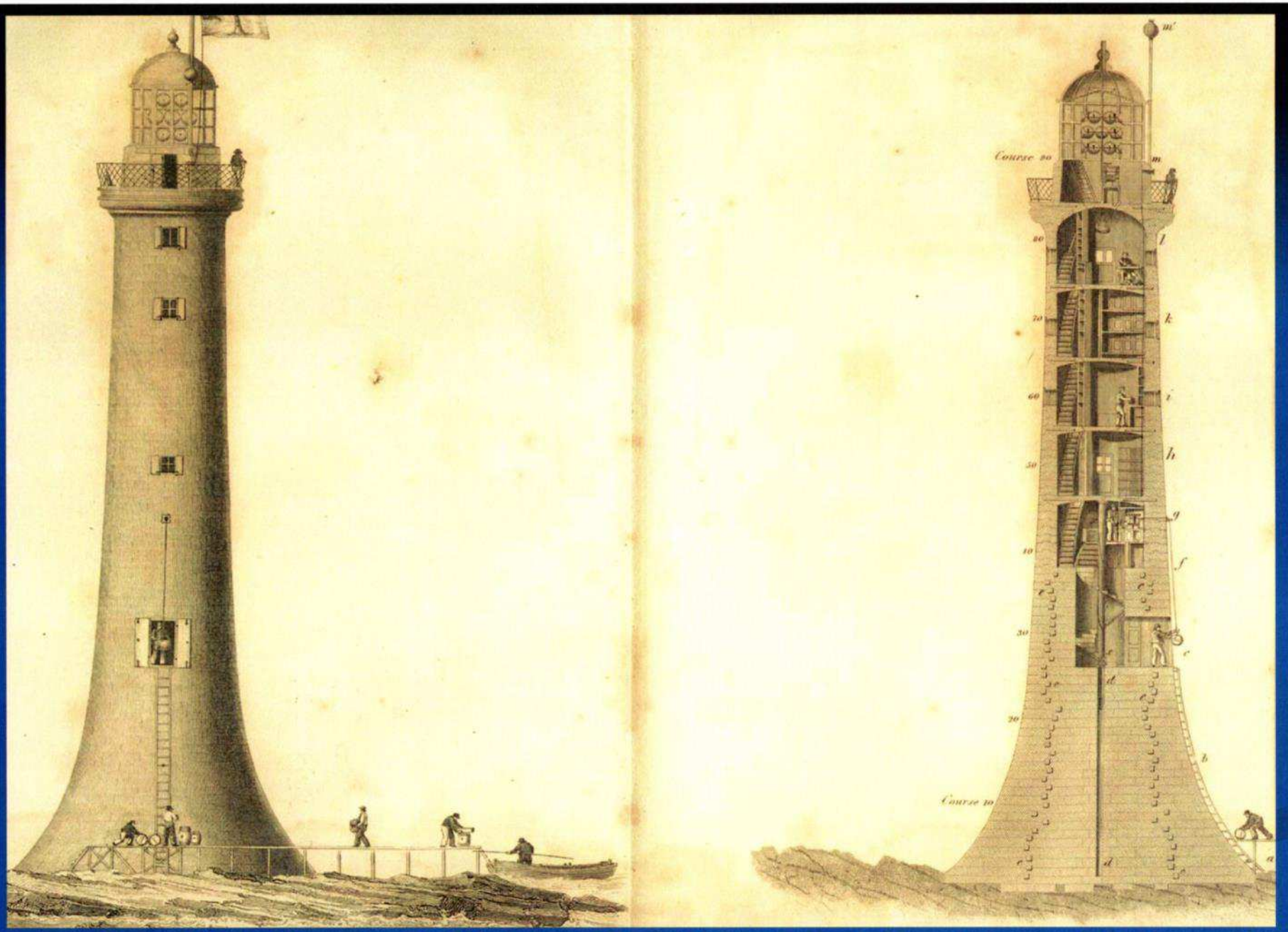
The ‘Library or Stranger’s Room’ finely finished. Furnishings included bookcase and books,tripod table, bible, antique lighting and Turkey carpet until 1960s. In 1986 - the kitchen.



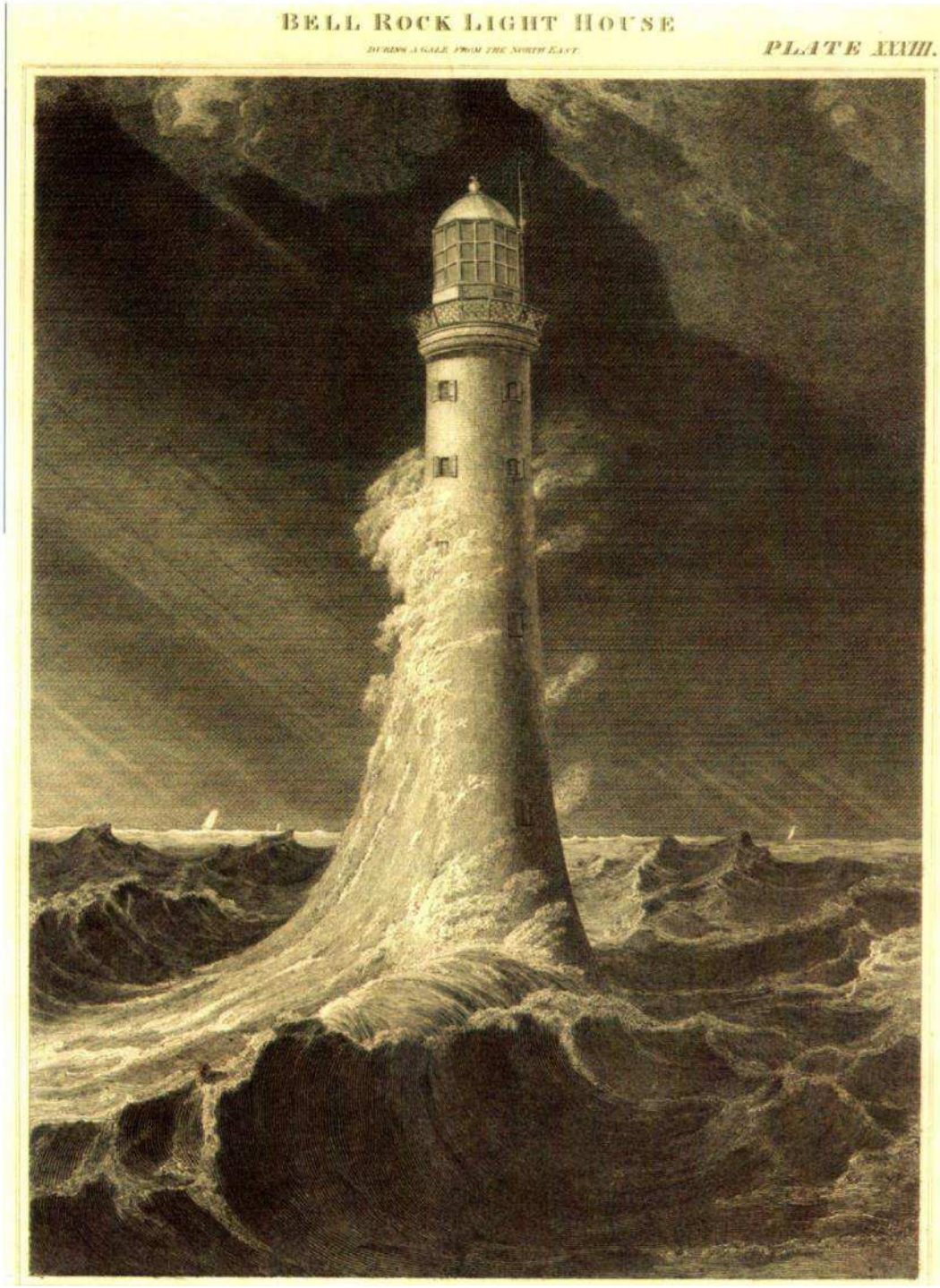
Overall activity at the Rock in July 1810



Light-room with, on a revolving frame, 4-sided array of 20 silvered-copper reflectors and Argand lamps with red glass at 2 ends (at Cape Bonavista Canada,1843) Note: gravity operated rotating mechanism to frame, signal ball, fog bells, ornamental cast-iron balustrade, kitchen chimney and, cantilever and suspended span joints in Craigleith stone floor and top of dome of the 'Library or Strangers Room'.



Completed lighthouse 1811. Cost £61,331. 9s 2d Contains 28,530 cu.ft stone and weighs 2,076 tons. Light first exhibited 1 February 1811



The lighthouse during a gale from the north east. Engraving by W.& D. Lizars, Edinburgh, from a drawing prepared under Robert Stevenson's direction by his later assistants W. Lorimer and John Steedman to illustrate his article on the lighthouse in an *Encyclopaedia Britannica Supplement* first published in December 1816 and again in 1824. The project's success enabled Stevenson to found a 150 year engineering dynasty.