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Great Pyramid Metrology and the Material Politics of Basalt*

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Astronomer Charles Piazzi Smyth's 1864–65 expedition to measure the Great Pyramid of Giza was planned around a system of linear measures designed to guarantee the validity of his measurements and settle ongoing uncertainties as to the Pyramid's true size. When the intended system failed to come together, Piazzi Smyth was forced to improvise a replacement that presented a fundamental challenge to the metrological enterprise upon which his system had been based. The astronomer's new system centered around a small lump of basalt, now held at Cambridge's Whipple Museum of the History of Science, which nucleated a wide array of material and scientific considerations. Through a bipartite analysis of the physical and narrative dimensions of Piazzi Smyth's basalt Standard, I develop the implications of its use and construction for understanding the material constitution of scientific instruments. In particular, I illustrate how instruments are locally constituted through co-accountable systems and how their material features become integrally implicated in both their uses and meanings.

I. INTRODUCTION

In November 1864, Scotland's Astronomer Royal Charles Piazzi Smyth embarked on a six-month expedition to measure the Great Pyramid of Giza. The voyage came on the heels of a crisis in British Imperial metrology emblemized by Parliament's long-anticipated legalization, earlier that year, of the French metric system for contracts and commerce (Reisenauer 2003, 942). Piazzi Smyth's mission was no less than to resolve the failures of British metrology once and for all. His method: to definitively prove the primacy of British measures by finding them built into

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the very stones of "the primeval world's greatest wonder" (Smyth 1867, 1:viii; 1874, 454).

This paper examines how Piazzi Smyth could hope to capture the timeless dimensions of the Great Pyramid and bring them safely back to Britain. The astronomer's accomplishment, such as it was, rested on the combined material and rhetorical achievement of standardized length. This dual production shall be analyzed through a bipartite account of a single, pivotal instrument from the expedition–a small lump of basalt marked with a five-inch scale. By weaving together Piazzi Smyth's descriptions and my own inspections of the stone, I aim to adumbrate the complex relationship between the values and materials of scientific instruments.

The basalt fragment offers an uncommonly rich view of material instruments in action in part because it was not included in Piazzi Smyth's planned linear measurement apparatus. In the run-up to the expedition, the astronomer had conceived of an elaborate measuring system comprising "A numerous and heterogeneous family" of measuring rods adapted to different tasks and circumstances, all of which would be compared, before and after each measurement, to a single hundred-inch wood Reference Scale. The Reference Scale, in turn, was to be verified by means of a specially commissioned micrometer-microscope beam-compass against an even more permanent and invariable stone Standard Scale, the "veritable keystone of our measuring system" (Smyth 1867, 1:273-74, 1:279, 2:6-10; Figure 2).

But things did not go as planned. The Reference Scale became so warped in the "heat and drought of Egypt" that it was unusable (Smyth 1867, 1:274, 1:282, 2:7). The commissioned Standard Scale and micrometer-microscope beam-compass were judged at the last minute to be "made quite contrary to instructions, and very ineffective" (2:8). Piazzi Smyth was forced to improvise a new way to certify his measures. "The most important part of the whole system" became "a very dense block of solid black stone" which Piazzi Smyth found near the Pyramid (1:274; Figure 1). The fate of the entire expedition came to rest on a single lowly lump of basalt.

Piazzi Smyth's frantic scramble to improvise a new means of verifying his measures has been overshadowed by other more colorful features of his account. Extant literature on the expedition includes revealing discussions of the astronomer's ties to British Israelism (Reisenauer 2003), "the invention of tradition" in Victorian metrology (Schaffer 1997, 438-59), and the machinations of single-minded obsession (Brück and Brück 1988, 95-104).[1] Without aiming to downplay the importance of

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[1] See also Smyth (1870); Schaffer (2000), 83. Of particular importance in these

Figure 1. Piazzi Smyth's Great Pyramid measure, marked with 5-inch standard, 1865. Wh.1155. Photographs in this and subsequent figures are courtesy of Joshua Nall, with permission from the Whipple Museum of the History of Science, University of Cambridge.

these rich and provocative circumstances to a final accounting of Piazzi Smyth's undertaking, I would like to suggest that embedded in the astronomer's basalt scale there lies an important and hitherto missing material side to the story. Beneath the dazzling menagerie of Piazzi Smyth's manifold ideological entanglements is an episode in the material history of national metrology whose study holds the potential to enrich our understanding of both the astronomer's work in particular and the nature of scientific instruments in general. That episode's plot traces the deceptively straightforward question of why the expedition's most mundane instrument came to be, for Piazzi Smyth, its most important one.

II. TWO METROLOGICAL CRISES

Following Latour and Woolgar (1986, 50-51), my analysis begins with the principle that a scientific instrument is a means of transforming material objects. Such objects can be brought into contact with other objects, change their form, or be translated into graphs, numbers, or other inscriptions. Through a process Lynch (1985, 10) calls *rendering*, instruments allow scientists to submit objects from the natural world to a long series of transformations so that they may take the form of accountable scientific data.

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analyses are the astronomer's relationships with eminent astronomer John Herschel and provocative publisher John Taylor, as well as his project's immense debt to seventeenth-century Orientalist John Greaves (see Greaves (1646), Shalev (2002)), which will be set aside in favor of the more specifically material questions of my account. For further context in the history of Pyramidology, see Herz-Fischler (2000) and Rossi (2006).

One fundamental question, often elided in instrument studies, concerns what it is about those instruments that allows them to mediate these crucial transformations. For it is manifestly not the case that any instrument will do. Scientific practitioners choose and use their instruments deliberately and with great care in order to be able to effect the material and semiotic metamorphoses upon which their work relies. In Piazzi Smyth's case, this choice became dramatically visible in a way highly unusual in historical accounts of scientific instruments. His example helps us begin to explain an instrument's particular relationship to its project in a Science Studies context where instruments often seem merely incidental to their own functioning.

Metrological instruments offer a particularly vivid way to study the transformations at the heart of instrumental science. As O'Connell (1993), Schaffer (1992, 1997, 2000), Latour (1986, 27; 1987, ch. 6), Golinski (1995), and others describe, metrology entails the instrument-mediated (and value-laden) local translation of natural and artificial quantities from one form to another in order to effect globally valid measurements of objects and phenomena. It thus makes vivid the universal aspirations of all instrumentally (and hence, locally) produced scientific data. In Piazzi Smyth's case, measuring rods and other surveying instruments were used to translate spatial features of the Great Pyramid into numerical measurements. But these instruments, in turn, could only ever produce what Piazzi Smyth calls "reputed inches," that is, measurements relative to the idiosyncrasies of their particular instrument.[2] The metrological program involves reconciling such reputed measures according to standards that allow them to be compared and interpreted globally.

The metrological program's principal manifestation over the course of its history has been in the problem of national metrology. Originating as a means of standardizing commerce and routinizing associated elements of statecraft, national systems of weights and measures were endowed with a pervasiveness and symbolic authority that made them into powerful ideological battlegrounds.[3] The standards regime in place in Piazzi

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[2] In fact, Piazzi Smyth had a slightly broader meaning for reputed inches that simultaneously implicated the relativity of national systems of measurement and regimes of standardization, a relativity with profound ideological implications underpinning his aim to rectify and justify the British inch. I suggest here that this aim is more closely related to matters of material metrology than is commonly assumed.

[3] Schaffer (1997) outlines the values and institutions of Victorian metrology and provides a bibliography for the subject (467-468). See also Seymour (1980), Warner (1990), Schaffer (1992, 2000), Alder (1995; 2002), Bourguet (2002), Shalev (2002), and Connor and Simpson (2004). Piazzi Smyth (1864) gives his own polemical history of British national metrology, dating to the Magna Carta.

Smyth's time dated back to the Weights and Measures Act of 1824, whereupon geodesist Henry Kater was commissioned to produce a series of official standard measures. Kater's standards were to be the nexus of a "top-down" metrology, stabilizing all other measures by offering an Archimedian fixed point of reference. Top-down standards regimes rely on the fixation of a single official embodied standard, such as Kater's yard or the official meter in Paris, against which all comparable measures are to be calibrated either directly or indirectly. They rely on both an effective system of calibration and the ultimate stability of the official standard. Unfortunately, Kater's standards were among the casualties of an 1834 fire in the Houses of Parliament. It would take decades to replace them, exposing in the process many of the frailties besetting the prevailing approach to British national metrology (Airy 1857; Piazzi Smyth 1864, 306, *et passim*).

Piazzi Smyth's measuring system faced a similar fate. Like the official Kater yard, Piazzi Smyth's commissioned Stone Standard was to provide an expertly-tuned fixed reference point with which to calibrate linear measures on the expedition. Using expensive, high-precision equipment, the astronomer would ensure that each measurement taken from the Pyramid was ultimately accountable to the Stone Standard Scale (Figure 2).

But fate intervened, and Piazzi Smyth was left without the standard that was to certify the entirety of his data. Unmoored from the linear metrological standards that could validate his measurements in a distant land, the astronomer faced a metrological crisis of his own. His response, as much a matter of practical necessity as ideological convictions, was to abandon the top-down Kater approach in favor of a "bottom-up" approach inspired by the Great Pyramid itself. Such a bottom-up metrology replaces the top-oriented system of calibration in the top-down approach, where the object of calibration is to compare each measure with the single official standard, with one where each object has the potential to be a standard and the stability of each calibration becomes the system's central feature. In Piazzi Smyth's pre-expedition writings, heavily influenced by John Taylor's (1864) interpretation of the Early Modern metrology of John Greaves (see Shalev 2002, 571-72), the Pyramid served as a Kater yard of all Kater yards, an enduring "metrological monument" capable of delivering a "universal metrology" by holding in its stone edifice an unchanging record of its measures (Smyth 1864, 368, et seq.). While the astronomer's later rhetoric is recycled from these earlier works (cf. Smyth 1867, 3:115), its register changes dramatically in the account of the expedition and the works that follow.

In Piazzi Smyth's improvised measuring system (Figure 3, explained

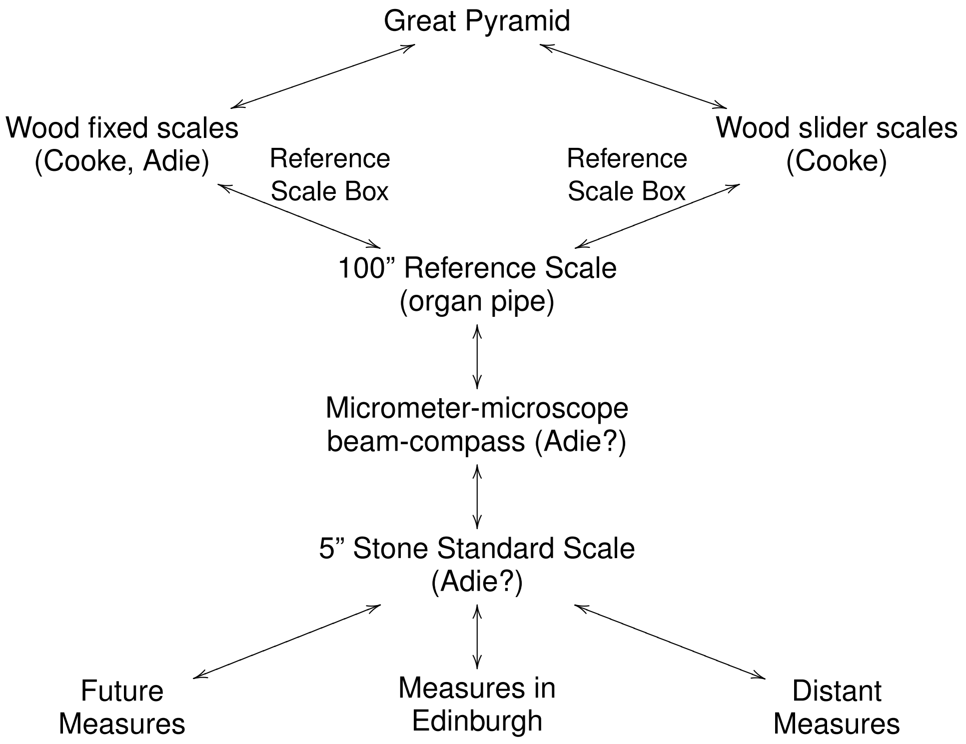

Figure 2. Piazzi Smyth’s intended measuring system, from descriptions in *Life and Work* (1867).

below), the Pyramid remains a vaunted timeless measure, but it is no longer the only such one. Now, his basalt measure would also prove its worth by “keep[ing] a record of the length of the inches with which the Pyramid was measured on the present occasion, to distant ages” (Smyth 1867, 1:274). Suddenly, the astronomer’s metrology required the fixing not of a single standard length but rather a single standard of accountability for lengths, based on the stability of their representatives.

The astronomer could then afford to do away with the highly-refined beam compasses and reference scales necessary in a top-down regime. Unable to set official standards in stone, he made his stone the standard. As long as his instruments could be calibrated within his system, it was not necessary that they be meticulously linked to external guarantors of accuracy. In this bottom-up metrology, measuring instruments would be systemically correlated, with every link in the system a potential locus of calibration.

This also explains why the astronomer reports verifying his system, on his return to Edinburgh, against a surviving copy of Kater’s yard which he

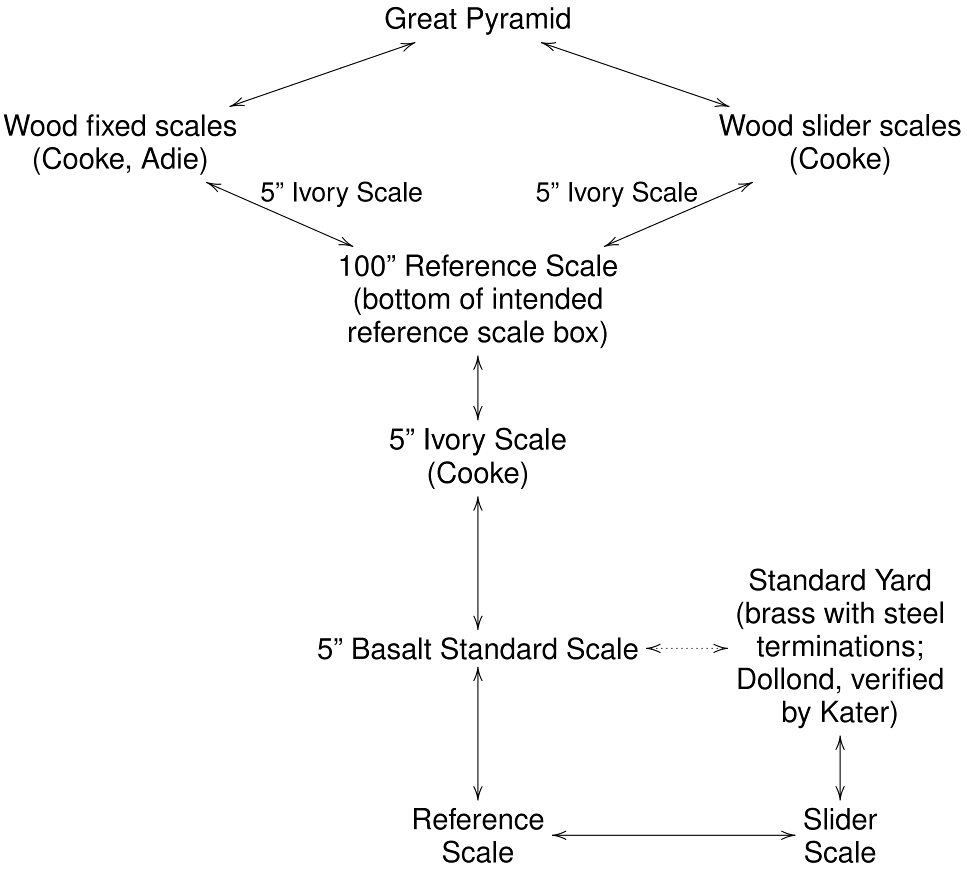

Figure 3. Piazzi Smyth’s actual measuring system, from descriptions in *Life and Work* (1867).

knew to have been defunct as an official standard for decades (Smyth 1864, 177-80). Metrology’s value of precision was replaced, in Piazzi Smyth’s metrology, by its complementary value of permanence. A measure need not be official, so long as it was lasting. No longer able to make an official calibration in Egypt, Piazzi Smyth enacted an *ad hoc* system based on the revisability of all calibrations, and thus the imperative that any standard survive to be re-calibrated. Any standard could be like the Great Pyramid, and the so-called “Battle of the Standards” (Taylor 1864) would be won not by the standard best grounded in the laws of men or Nature but by the standard which could withstand the test of time.

Most scientific instruments are not so directly linked to their “Kater yards” as Piazzi Smyth’s intended standard would have been to the official standards on which it was to have been based. The astronomer’s response to his own metrological crisis emphasizes the irreducible locality of all

(a) (b)

Figure 4. The left (a) and right (b) sets of vertical marks.

instrumental productions. Upon the replacement of just two of its many links–the Stone Standard and Reference Scale–his measuring system shifted its source of authority from the official (top-down) to the locally accountable (bottom-up). For this shift to take place, Piazzi Smyth needed to produce a standard for his system worthy of the authority he would vest in it. This production centered on what I am calling the material politics of basalt.

III. THE MATERIAL POLITICS OF BASALT

To resolve his expedition's metrological crisis, Piazzi Smyth re-founded his measuring system in the basalt fragment's durability, a property deriving from both the stone's substance and its narrative. This section traces that value-laden materiality through its physical and textual manifestations. Physically, the basalt Standard is deceptively plain. Now held in the Whipple Museum of the History of Science in Cambridge, England, it is mounted between two Adie & Son thermometers in a mahogany box built at the Pyramid, complete with brass hinges and fittings for a lid that was lost sometime in the century between the box's construction and its accession at the museum. Accompanying the standard in the Whipple collection is an 1881 commemorative five-inch wood scale made by James M. Bryson, evidence of Piazzi Smyth's popular reception in the decades following his return from Egypt. The stone's five inches are marked on a double horizontal line across the worked top surface of the otherwise irregularly shaped stone, nested between two sets of vertical lines. Each of these sets consists of two short perpendiculars and a third longer line halfway between them, accompanied by sets of marks which were used to determine where to inscribe the longer perpendicular (Figure 4). Above the scale, Piazzi Smyth inscribed the words "5-inch Standard, at Great Pyramid 1865 C.P.S." (Figure 5).

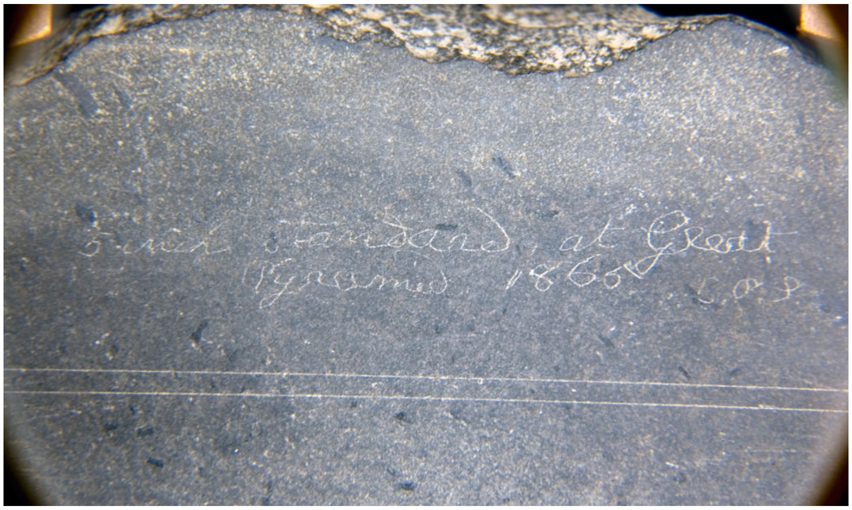

Figure 5. Piazzi Smyth's inscription.

Piazzi Smyth does not anywhere specify how the five inches of his scale were determined, but a close examination permits the following conjecture. One can see the order in which the lines were traced from the grain of the engravings at their intersections. The astronomer began with the long horizontal lines, traced against a straight-edge, followed by the two shorter pairs of vertical lines. In his inventory of linear scales, Piazzi Smyth lists two five-inch ivory scales supplied by the respective optical firms of Cooke and Adie and differing in actual length by one-thousandth of an inch (Smyth 1867, 2:2). The dimensions of the vertical marks and the slight difference in horizontal spacing between the paired lines on either end of the scale are consistent with the astronomer having traced along the sides of the Adie scale and along the Cooke scale about one tenth of an inch to the right of the Adie marks, so as to use their average length for his official standard. He did this by finding the midpoint between respective pairs of vertical lines along each of the horizontal ones using the finely sub-divided Cooke measure, which was used throughout the expedition for making comparisons between the basalt Standard and his other measures (2:2, 8).

Not trusting a single such determination, he repeated the measurement three times against the bottom horizontal line and then twice against the top one, marking the measured midpoints with increasingly confident strokes to the left and right at each measurement. Each such determination was done with subdivisions on a different part of the Cooke scale in order to account for minor variations in its construction. Next, he connected the two midpoints on each side with a longer vertical line traced along a straight-edge, a task only possible because the slight convexity of the stone's extremities allowed a short scale to sit levelly on the part of the surface to be engraved. Finally, with his five inches in place, the astronomer placed letters at either end of the scale and engraved the Standard's length, location, and provenance across the top.

Consistent with its exacting verification against an out-of-date Kater yard, Piazzi Smyth spared no effort in the meticulous production of a standard of length for his expedition that he knew to be ultimately arbitrary. There is no discernible scientific explanation for his apparent preference for the average of his two five-inch scales, nor for the excess of care with which he undertook his engraving. Indeed, the most plausible purpose for the exacting procedure just reconstructed is a symbolic one, which must be understood in the context of the features of the stone that do appear in his written accounts.

Discussions of the stone can be found in both the narrative first volume and technical second volume of Piazzi Smyth's (1867) *Life and Work at the Great Pyramid* (1:273-295, 2:8-10). He dwells primarily on two topics: the failings of the optician originally commissioned to construct a Standard Scale in England, and his search for a suitable stone fragment with which to make a replacement in Egypt. Both discussions invest Piazzi Smyth's simple measuring instrument with a monumental array of norms and values.

Little invective is spared for the unnamed optician who, in the account, earns only such sardonic appellations as "the great optician" (Smyth 1867, 1:275, 282).[4] Opticians, he claims, seek "almost superhuman mechanical accuracy" and can often be seen "apparently idling over unfinished work, but really thinking how the next step is to be accomplished..., perhaps, never before realized by mortal hand, or brain either" (1:276). Superhuman accuracy, however, was of no use in a standard whose material would not last.

Indeed, material considerations were at the forefront of the crisis in British standards. No substance was without its problems: wood would warp and decay, stones erode and crumble, cast metal alloys shrunk as they cooled, and forged metal notoriously would not retain its shape. Piazzi Smyth's inspiration came from within the heart of the Pyramid itself, in the form of "the Porphyry Coffer...with the tenacity and hardness of its substance unimpaired, and the polish and evenness of its surface untouched by nature through that length of time." The astronomer proclaims that the coffer's porphyry, a variety of granite, "realizes all that modern metrologists have been seeking for in principle,...and realizes

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[4] Circumstantial details point to Liverpool-based instrument-maker Richard Adie, who then headed his late father and brother's highly reputed Edinburgh firm Adie & Son.

their desiderata even to a higher degree than they had ever expected, or hoped, to find" (Smyth 1864, 313). As a stone, it was hard and inflexible, and less prone than metals to oxidation and variation under temperature changes. But as igneous rock, porphyry claimed the further advantages of cast metal, particularly with regard to shape retention, while avoiding its pitfalls because "it was cast...thousands, and even hundreds of thousands of years before the days of Noah" (314).

The astronomer's fascination with igneous rock reappears in his 1867 account, whose frontispiece depicts the very same porphyry coffer which captivated Piazzi Smyth before the expedition. In December 1864, before his arrival at the Great Pyramid, Piazzi Smyth recalls looking "with eyes rather covetous..., on certain basalt coffins [in the Museum at Boolak]...for the material was so remarkably fine in grain, besides being hard, and free from either fissure or fracture" (Smyth 1867, 1:284). A wandering series of awe-struck observations about the basalt's durability concludes with: "what a material must it not present for national standard scales of length; and how little doubt would there have been now upon the length of either the Greek or Roman foot, if their copies had come down to us engraved on a slab of *this* basalt" (1:286-87).

After a seven-page tale of his search for the perfect stone, Piazzi Smyth settles, with palpable disappointment, on a coarse specimen from near the Pyramid (Smyth 1867, 1:287-93). The task of grinding the stone fell to "Alee, the day-guard," who carried out the "tedious grinding...as if his arms had been part of a speculum-grinding machine" (1:293). A full day's work left the stone "odiously concave," so the astronomer modified Alee's procedure to produce, after "another sunrise to another sunset," a convex surface instead. Eventually, they managed "a surface...on which fine engraved lines could be creditably placed" (1:294). But, demonstrating its durability too well, "the hardness of the stone...resisted all attempts to put in the graduation with either a hard steel cutter or sharp flint edge" (1:294). Only with his wife's diamond ring could Piazzi Smyth finally make the necessary marks.

Alee and the optician appear as in a morality play, manifesting the triumph of the durable over the official. Where the optician is lost in thought and aims for superhuman perfection, Alee tirelessly discharges his task like the optician's own speculum-grinding machine, not even noticing the odious concavity he is producing. The optician lusts after the hitherto unachieved, Alee after an "extra penny in any honest manner" (Smyth 1867, 1:293). Ultimately, it was Alee's honest physical struggle that produced an instrument the optician's vain mental labors could not.

And yet, though a product of days of arduous exertion, the stone's surface is not nearly so even and regular as one might expect, nor are the engravings or lines so neat and precise. The extremities of the worked surface are lighter, somewhat rougher, and slightly convex. Three distinct levels of polishing are discernible, with the finest around the markings at either end of the scale (Figure 4). Lines in the less-polished regions appear rougher, and the stone's marks bear out the astronomer's struggles with inscription: the "1" of "1865" required two attempts, his cursive letters come out inconsistent, and even the metrologically important bisection marks near the junction points at either end of the scale consistently fail to meet where they ought to.

The same durability which made the basalt fragment an ideal candidate for Piazzi Smyth's Standard made the stone difficult to deploy as such. The just-good-enough manufacture of the physical object creeps back into Piazzi Smyth's narrative between the first and second editions of his polemical *Our Inheritance in the Great Pyramid*, penned respectively before and after the expedition. In the second, he adds a lengthy discussion of "places of significant numbers" and declares that "Human practical science can only go on by approximations, and can never reach anything more than approximations" (Smyth 1874, 42-43).

The basalt Standard held all of these values and forced all of these negotiations, even though there are only six documented cases of its use: three in Egypt and three in Edinburgh, all by the astronomer himself (Smyth 1867, 2:8-9). This suggests that an instrument's materiality matters in a more fundamental way than can be traced merely to the physical circumstances of its use. Instruments such as Piazzi Smyth's basalt Standard embody values, principles, and *ways of doing* without having to be used or used successfully. The stone's meaning, in both the expedition and its narrative, came not from its use, *per se*, but from the ardors of obtaining it, and, having made it, the concomitant certainty in its ability to remain unchanged. It tied measures together not by constantly interrogating them but by promising to hold them eternally.

IV. Conclusion

Alas, the stone's promise was not borne out by history. As late as 1876, Alfred Russel Wallace praised Piazzi Smyth's measurements and called attention to his conclusions in front of the British Association (Wallace 1876, 411), but the astronomer's arguments had already brought him into conflict with such powerful foes as the Royal Society and Ordnance Survey. Ever-expanding editions of *Our Inheritance* continued to disseminate Piazzi Smyth's polemic until 1890, by which time Egyptologist Flinders Petrie's own decade-old measures of the Pyramid had largely discredited Piazzi Smyth's claims among scholars of consequence. Piazzi Smyth's metrology, as distinct from his measures and their public interpretation, appears largely to have been lost in the fray–a provocative case study, rather than a transformative innovation.

I have argued that Piazzi Smyth's basalt Standard Scale bears witness to two major considerations for material instruments. First, the Standard's deployment in a locally accountable system of Pyramid measures suggests the irreducibly local character of regimes of instrumental science. Though they are nearly always connected up to grand enterprises through repeated renderings and mobilizations, instruments never give up their reliance on bottom-up calibrations and deployments–something made clear when Piazzi Smyth's instrumental system suddenly lost contact with its purported top-down metrological underpinnings. The technical regimes that ultimately support top-down metrology appear, upon closer inspection and in moments of crisis, bottom-up through and through.

Second, the Standard demonstrates how an instrument's materials, functioning simultaneously as a resource and a burden for its users, are capable of embodying a wide range of norms and values. The rigors of the basalt Standard's construction undergirded its claims to validity, even as they undermined any possible aspirations to precision or perfection. Likewise, all scientific instruments are bound in use and meaning by their material features. Moreover, it is in the mundane material details of those instruments that decisive features of grand projects can often be found.

Piazzi Smyth's particular crusade to rescue the British inch, though popular for decades after his expedition, did not itself stand the test of time. It is a fitting tribute to the astronomer, however, that his purportedly ageless measuring apparatus continues to impart lessons on the nature of science and metrology, albeit not the ones he initially espoused.

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