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THE HALL OF HEAVENLY RECORDS

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朝鮮「書雲觀」天文儀器與計時機

周士一書

THE HALL OF HEAVENLY RECORDS

KOREAN ASTRONOMICAL INSTRUMENTS AND CLOCKS 1380–1780

JOSEPH NEEDHAM
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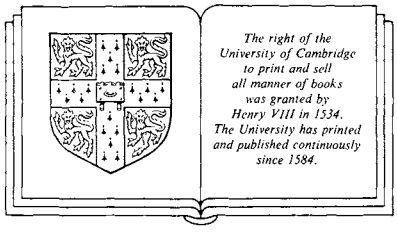

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A NOTE ON ROMANISATION AND OTHER CONVENTIONS

Names of Chinese persons, places, institutions, etc. are given in Wade–Giles romanisation, with the exception of a few familiar place-names that are widely recognised in older forms (Peking, Kaifeng, etc.). Korean romanisation follows the McCune–Reischauer system. In accordance with recently accepted standard practice, Korean personal names are not hyphenated, except in the case of Korean authors of works in English who hyphenate their own names. At the first appearance in each chapter of any Korean word or phrase we provide, in parentheses, its Chinese characters; except in the case of proper nouns, we also provide Wade–Giles Chinese romanisation for Korean terms. Words singled out for special attention in our translations are given in Chinese romanisation only, as the Korean historical annals are written in standard Classical Chinese. Characters and dates for the kings of the Yi Dynasty are given in the Appendix.

Dates are denoted as Before Common Era (B.C.E.) and Common Era (C.E.).

Where it is possible to specify exact dimensions in our discussions of instruments and the like, we employ metric units. The words 'feet' and 'inches', both in the translations and in our own text, refer to the Chinese ('Chou') foot (*ch'ih* 尺) and inch (*ts'un* 寸, i.e. $\frac{1}{10}$ of a *ch'ih*).

Within translated passages, words clearly implied by but not present in the original text, or that have been supplied to meet the requirements of English grammar and syntax, are enclosed in parentheses. Words that convey the translators' comments, amplifications, or other interpolations are enclosed in square brackets.

INTRODUCTION AND ACKNOWLEDGEMENTS

In this book we present a study of the astronomical instruments and star-charts of Korea – the Kingdom of Chosŏn 朝鮮 – during the greater part (*c.* 1392–1776) of the Yi 李 Dynasty. The focus of our study is the Korean Royal Observatory and Bureau of Astronomy, the Sŏun Kwan (Shu-yün Kuan 書雲觀, 'The Watch-tower for Recording Celestial Ephemera'), which we have styled 'The Hall of Heavenly Records'.[1] We have confined our investigations to the astronomical and horological instruments, celestial planispheres, and other physical paraphernalia of the Sŏun Kwan; we have not attempted a history of Korean observational astronomy and meteorology during the period in question, nor do we deal extensively with political and institutional concerns.

The materials for this study are drawn from two types of evidence: first a small but important array of physical objects, in the form of a few instruments and star-maps that have survived the ravages of warfare and time down to the present day, and secondly documentary evidence. The latter is found mainly in the 'Veritable Records' (*sillok*; *shih-lu* 實錄) of the various kings of the Yi Dynasty[2] and in a great Korean historical work, the *Chŭngbo munhŏn pigo* 增補文獻備考, the 'Comprehensive Study of Civilisation, Revised and Expanded'.[3] In what follows, we

[1] The name of this bureau was changed in 1466 to Kwansanggam (Kuan-hsing-chien 觀星監, 'Superintendency of the Observation of Celestial Phenomena'). See Jeon Sang-woon, *Science and Technology in Korea: Traditional Instruments and Techniques* (Cambridge, Mass. and London: MIT Press, 1974), p. 105. (Hereafter Jeon, STK.)

[2] The 'Veritable Records' of the Yi kings, collectively usually called the *Yijo sillok* 李朝實錄 or the *Chosŏn wangjo sillok* 朝鮮王朝實錄, were compiled from contemporary primary sources by special temporary bureaus set up after the death of each king. Some kings do not have 'Veritable Records', but rather 'diaries' (*ilgi*; *jih-chi* 日記). For various editions of the Veritable Records, see Tu-jong Kim, *A Bibliographical Guide to Traditional Korean Sources* (Seoul: Asiatic Research Centre, Korea University, 1976), pp. 61 ff, and Benjamin H. Hazard *et al.*, *Korean Studies Guide* (Berkeley: University of California Press, 1954), pp. 100–1. We have used a modern Japanese reprint edition, *Richō jitsuroku* 李朝實錄 (Tokyo: Gakushūin Institute of Oriental Culture, 1953).

[3] Officially compiled; published 1790, 1908. We have used a modern reprint edition published in Seoul by the Kosŏ Kan-haenghoe 古書刊行會, 1959.

present translations of long passages from these works relating to astronomical instruments and the like, and also (in Chapter 5) translations of inscriptions on an important surviving Korean star-map of the middle eighteenth century. Through a presentation and analysis of this evidence we have tried to identify and describe as precisely as possible the instruments of the Korean Royal Observatory, to explain their functions, and to show how they fit into the larger context of East Asian astronomy.

The question of context is an important one, for Korean astronomy was continually and powerfully influenced by that of its great neighbour China. Most of the instruments and other materials that we discuss below are, directly or indirectly, of Chinese ancestry. Accordingly, we have tried wherever possible to trace that line of descent, paying particular attention to the instruments of the great Astronomer Royal of the Chinese Yüan Dynasty, Kuo Shou-ching 郭守敬 (*c.* 1280 C.E.), and to the works of the Jesuit astronomers of the Chinese Mission at Peking, whose Shih-hsien 時憲 calendar (adopted by the Ch'ing Dynasty in 1645 and by the Yi court in 1651), along with their other astronomical writings, wrought important changes in the theoretical basis of Sino-Korean astronomy. The question of context also bears on the pace and timing of the activities of the Korean Royal Observatory. Because of Korea's political status as a tributary of the Chinese empire, the two greatest eras of astronomical instrument-building in the Yi Period (the early fifteenth and middle seventeenth centuries) were to an important extent responses to the consequences of dynastic overthrow and renewal in China, as well as being evoked by circumstances that were more directly confined to Korea itself.

The plan of this work is as follows:

In Chapter 1 we present a brief introduction to the theoretical background to Chinese and Sino-Korean astronomy, discussing cosmological, calendrical, horological, and mechanical matters that are essential to an understanding of what follows. We then briefly discuss the historical background to the first great period of astronomical instrument-making in the early Yi Dynasty, namely the fall of the Mongol Yüan Dynasty of China, the subsequent fall of the Korean Kingdom of Koryŏ 高麗, and the reigns of the three great early Yi kings, T'aejo 太祖, T'aejong 太宗, and Sejong 世宗.[4]

In Chapter 2 we describe and discuss the instruments made by order of King

[4] The (posthumous) names and reign-dates of the Yi Dynasty kings are given in the Appendix.

Sejong in his re-equipping of the Royal Observatory in the 1430s. These included, among others, armillary spheres,[5] copies of Kuo Shou-ching's Simplified Instrument (the 'equatorial torquetum'), a variety of sundials, and two complex mechanical clepsydras.[6] We present and comment upon translations of descriptions of the instruments from the *Sejong sillok* and the *Chŭngbo munhŏn pigo*, and discuss the operating principles of the instruments; where possible, we present as well photographs of surviving instruments, or reconstructional drawings based on the literary descriptions.

In Chapter 3 we discuss the fate of King Sejong's instruments, as they were repaired, replaced, or augmented in succeeding reigns. Most of them were destroyed in 1592, when Korea was invaded by Japanese armies under the great general Hideyoshi. The task of replacing them was slowed by further invasions of Korea, this time by the Manchus, in the early and middle seventeenth century; but after the Korean adoption of the Ch'ing (Jesuit-inspired) Shih-hsien calendar in 1651, a new burst of instrument-making activity occurred. In the latter part of this chapter we discuss the making of several important horological instruments in the 1660s, and then follow the aftermath of this story through the reign of King Yŏngjo 英祖 (to 1776).

Chapter 4 presents a detailed technical description of the most important, and only surviving, horological instrument among those from the reign of King Hyŏnjong 顯宗 described in Chapter 3, namely the 1669 armillary clock of Song lyŏng 宋以穎 incorporating an armillary sphere of Yi Minch'ŏl 李敏哲.

Chapter 5 (a revised version of a previously published article by Needham and Lu) presents a similarly detailed description of a Korean astronomical screen of the mid eighteenth century. This chapter provides us with a further opportunity for

[5] Armillary spheres are nests of rings which represent various significant great circles of the celestial sphere (the equator, ecliptic, meridian, horizon, etc.). In these pages we shall encounter two types: *observational* armillary spheres, designed to be used (usually with a sighting alidade or tube) to plot the locations and movements of the heavenly bodies; and *demonstrational* armillary spheres, designed simply to model the heavens for the contemplation of onlookers. In either case, the armillary sphere was usually designed so as to allow various rings to be rotated about an axis, either manually or mechanically. See Joseph Needham, *Science and Civilisation in China*, vol. III (Cambridge: Cambridge University Press, 1959), pp. 342–54 *et seq.* (Hereafter Needham, SCC.) See also below, Ch. 2, n. 11, on pp. 20–1.

[6] A clepsydra is any timekeeper operated by means of a regulated flow of liquid into ('inflow type') or out from ('outflow type') a vessel where it is measured. The clepsydras discussed in these pages are of the inflow type. Special kinds that will be encountered here include the *float* or *float-rod* clepsydra, in which a float in the inflow vessel carries a visible rod marked with divisions of time, and the *anaphoric* clepsydra, in which a string from the float imparts rotary motion to an axle or drum. Either type could be used to transmit power to the mechanisms of a *striking* clepsydra to operate audible (and sometimes also visible) time signals.

discussing the background of Chinese Jesuit astronomy and its influence on Korea.

We conclude our book with an epilogue that touches briefly on events in the last part of the Yi period.

The authors hope that this study of the instruments of the Korean Royal Observatory will lead others to take up an investigation of the many unresolved questions, including the history of observational records,[7] that still remain in the field of Korean astronomy. The bibliography is designed as an aid to those who may wish to pursue this interesting and rewarding task; for their benefit it includes some entries not directly mentioned in our text and footnotes.

In a work published in 1905, an ardent friend of the Korean people made the following observation: 'In 1550 . . . an astronomical instrument was made, called the . . . "Heaven Measure". We are not told the exact nature of the instrument, but it implies a considerable degree of intellectual activity and an inclination toward scientific pursuits that is rare in Korea.'[8] This assertion could hardly be more mistaken. It reflects prejudices to which no responsible scholar today could subscribe, but which have died a most reluctant and lingering death: namely that East Asia has produced little science worthy of the name, and that Korean science has been but a pale reflection of that of the Chinese. The great flowering of historical studies of Chinese science in recent years has done much to eradicate the first prejudice, while the great pioneers of the study of traditional Korean science, Carl Rufus and his collaborators and (a generation later) Jeon Sang-woon, have done much to demolish the second.[9]

Our study of the instruments of the Korean Royal Observatory, which builds on the labours of Rufus and Jeon, has convinced us that while Korean astronomy

[7] Some Korean observational records, mostly those in the official histories, have already been used by Chinese scholars; see for example the article by Hsi Tse-tsung (Xi Zezong) 席泽宗 and Po Shu-jen (Bo Shuren) 薄树人, 'Chung Ch'ao Jih san-kuo ku-tai ti hsin-hsing chi-lu chi ch'i tsai she-tien t'ien-wen-hsüeh chung ti i-i' 中朝日三国古代的新星纪录及其在射电天文学中的意义, *T'ien-wen hsüeh-pao* 天文學報 (*Acta Astronomia Sinica*), 1965, *13*.1: 1–22, tr. as S. R. Bo and Z. Z. Xi, 'Ancient Novae and Supernovae Recorded in the Annals of China, Korea and Japan and their Significance in Radio Astronomy', NASA TT-F-388 (Technical Translations Series), 1966. Other observational records probably remain in MS. from among the Korean government archives, and we may hope that someday they will become available to scholars.

[8] Homer B. Hulbert, *History of Korea*, 2 vols. (1905; repr. ed. Clarence N. Weems, 2 vols., London, 1962), I: 334.

[9] See the publications of Rufus, and Jeon, listed in our bibliography.

was indeed based solidly on that of China, it also had important indigenous features, wrought significant changes upon Chinese ideas and techniques, and incorporated influences from the Peking Jesuits (and, to a lesser extent, from Japan) in ways that sometimes differed from the acceptance of those influences in China. Korean astronomy was, in other words, a true national variant of the East Asian astronomical tradition; the instruments and written records that it produced are a valuable legacy to the history of science everywhere.

We think it appropriate, therefore, to consider here some of the implications of Hulbert's statement that 'an inclination toward scientific pursuits ... is rare in Korea'. He may have been thinking of the passing situation in his own time, but it is fair to say that modern historians of East Asian science have come to a precisely opposite conclusion. Twice in *Science and Civilisation in China* the writers were moved to say that 'of all the peoples on the periphery of the Chinese culture-area, the Koreans were probably the most interested in science, mechanical technology and medicine'.[10] No Korean embassy went to Peking during these centuries without asking for the latest books on astronomy and mathematics, on geography and medicine. The envoys also asked for samples of instruments too and, as we shall see in Chapter 5, in Jesuit times at least they got them liberally.

The most widely held stereotype of the Kingdom of Chosŏn is that, after the days of its first few great monarchs, it wallowed in stagnation brought about by a dry Neo-Confucian orthodoxy and bureaucratic factionalism. That stereotype is in fact false, the product of an imperialist mentality, seen in the self-serving writings of Western missionaries and Japanese colonialists.[11] The Yi Dynasty was indeed committed to a Neo-Confucian ideology; and Confucianism has sometimes been seen as the villain in the 'failure' of China and the countries in its cultural orbit to experience a scientific revolution. Yet the activities that we describe in this book contradict the notion of Neo-Confucian 'intellectual stagnation' in Korea; and there is no evidence whatever to suggest that King Sejong's instrument-builders and King Hyŏnjong's horologists were any less staunch in their orthodoxy than the rulers they served. Moreover, to see Neo-Confucianism as necessarily an enemy of science is a bizarre idea in itself, for many have concluded that its world-view was very congruent with that of modern science,

[10] Needham, SCC III: 298, 302, 389–90, 431, and a special appendix devoted to Korea, pp. 682–3; SCC IV.2: 516–22, esp. p. 519; SCC IV.3: 453; SCC V.2: 201; SCC V.3: 167, 177.

[11] We are grateful to Dr Gari K. Ledyard and to Dr Nathan Sivin for useful discussions on this point.

much more so indeed than that of traditional Western theology and philosophy.[12] To have a glimpse of evolution, and to build one's whole universe out of *ch'i* 氣, matter-energy, and *li* 理, pattern-principles at all levels, betokened remarkably enlightened minds.[13]

Akin, though opposite in intent, to Hulbert's anti-Confucian bias is the view that Confucianism and science were antithetical in another sense: that such things as the instruments we describe herein were triumphs of a Confucian society, but that they were not science. King Sejong, in this view, cannot be described as a patron of science despite his having spent a fortune on, and taken a strong personal interest in, the construction of new astronomical instruments. Rather, he was simply a more than usually competent monarch doing his job; that job included having an observatory, so he built one. Or again, in this view, King Sejong's rain-gauges had nothing to do with science, because they were part of a larger scheme for reforming the basis of land-tax assessment. The perceptive idea that measuring precipitation could give valuable information about the differential productivity of agricultural land was, it would thus be maintained, not 'scientific', but merely an example of administrative intelligence.

We take note of this view only in order to reject it firmly. It seems to us to arise from a fundamentally false historical perspective; yet here, in the history of science, a correct one is truly a *sine qua non*. In our view China, Korea, India, and the Arabs all had science, as also the ancient and medieval Europeans, and all made valuable contributions to it. But *modern*, ecumenical, and universal science, in other words the science of the Scientific Revolution, originated only in Europe during the late Renaissance. It is useless to look for hydrodynamics, electronics, or organic chemistry in ancient and medieval civilisations, or to complain of their absence, for these things are characteristic of modern science. During the past three centuries this has spread throughout the world, and there is no one, of whatever race, sex, colour, or creed, who cannot use it and add to it if once trained in it. Modern science, based upon the mathematisation of hypotheses about Nature, and upon relentless experimentation, has shed the ethnic limitations

[12] Needham, SCC II: 472 ff, 493 ff.

[13] This is borne out by Yung-sik Kim in his 'The World-View of Chu Hsi (1130 to 1200): Knowledge about the Natural World in the *Chu Tzu Ch'üan Shu*' (unpub. doctoral thesis, Princeton University, 1979), though Kim is critical enough of the details of Neo-Confucian proto-scientific observations and conclusions. Also relevant to this point is the excellent doctoral dissertation of Park Song-rae, 'Portents and Politics in Early Yi Korea, 1392–1519' (unpub. doctoral thesis. University of Hawaii, 1977).

which characterised the ancient and medieval sciences of various cultures; but these are not, as some have believed,incommensurable and eternally incompatible, like forms of artistic creation – they all embodied real advances in human knowledge; they were part of one single great movement in social evolution. Ever since man became able to observe, to reason, and to record, Nature has been much the same, so that all advances in natural knowledge, however haltingly the theories about them were expressed, have been real and durable. It was only in Galileo's time that the best method of discovery was itself discovered. In other words, we visualise the sciences of all the traditional ancient and medieval civilisations flowing into the ocean of modern science like rivers to the sea.

It would thus be culture-bound and deeply unfair to deny the name of science to the many scientific traditions which existed before our own modern science of the post-Renaissance West. The systematic application of human intelligence for the acquisition of knowledge about the natural world (whether for its own sake or in order to accomplish tasks through the development of technology) has been a universal human activity, and that activity is science. The Korea of the Yi Dynasty was profoundly Confucian, culturally proud, dynamic, and engaged in the science and technology of astronomy and horology in ways that ought to capture the imagination of all who are interested in the history of mankind's continuing discovery of the world of Nature.

In order to thank the many friends on whom we have relied for assistance and advice, we should like to describe briefly how this book came to be written.

In the 1950s, in the course of research which was to result in the book *Heavenly Clockwork*,[14] Joseph Needham, Wang Ling, and the late Derek J. de Solla Price became aware of a Korean demonstrational armillary sphere that had first been described in Western literature by Rufus and Lee in 1936.[15] Rufus's photograph of that instrument was reproduced as Fig. 59 of *Heavenly Clockwork*, and again as Fig. 179 in volume III of *Science and Civilisation in China*.

During the Japanese occupation of Korea, the instrument had been in the collection of Mr Kim Sŏngsu, who later presented it to the Koryŏ University

[14] (Cambridge, Cambridge University Press, 1960; hereafter Needham, Wang, and Price, HC.)

[15] W. Carl Rufus and Lee Won-chul, 'Marking Time in Korea', *Popular Astronomy*, 1936, *44*: 252–7; also Rufus, 'Astronomy in Korea', *Transactions of the Korea Branch of the Royal Asiatic Society*, 1936, *26*: 1–52, pp. 38–9 and Fig. 26.

Museum in Seoul.[16] Further enquiries showed that the instrument had fortunately survived the Korean War of 1950–3. Derek Price, with the co-operation of Dr Silvio Bedini, attempted to obtain the approval of the Korean authorities for the transport of the instrument to the Smithsonian Institution for a period of study. It was not possible to arrange for that to be done, but the enquiries had the good effect of stimulating the interest of the Korean government in the instrument, with the result that it was soon registered as a National Treasure.

Early in 1962, John Combridge's collaboration with Joseph Needham in the further study of East Asian clockwork mechanisms resulted in the translation, in draft, by Needham and Lu Gwei-djen, of chapters from the *Sejong sillok* and the *Chŭngbo munhŏn pigo* relating to scientific instruments. Study of these passages led, *inter alia*, to the belief that the instrument in the Koryŏ University Museum might be that constructed in 1669 by Song Iyŏng, incorporating an armillary sphere made by Yi Minch'ŏl. The importance of the identification of that instrument, if the hypothesis were to prove correct, prompted further efforts at investigation.

In 1963 the aid of Professor Gari K. Ledyard, then resident in Seoul, was enlisted in obtaining photographs of the demonstrational armillary sphere and its clockwork mechanism. Through the good offices of Dr Jeon Sang-woon of the Sungshin Women's Teacher's College, Seoul, and with the kind co-operation of Professor Kim Chŏnghak, Director, and Mr Yun Seyŏng, Curator of Historical Collections of the Koryŏ University Museum, Ledyard was able, the following year, to supply Needham and his colleagues with an excellent set of thirty detailed photographs. Several similar photographs were subsequently published for the first time by Jeon in *Science and Technology in Korea* (1974).[17]

The photographs became the basis for a detailed study of the instrument by Combridge, which was completed in draft in 1964.[18] That study reinforced the belief that the instrument was indeed that of Song Iyŏng and Yi Minch'ŏl. It was

[16] Kim Sŏngsu, a noted antique collector, was an important industrialist, the founder of Korea's leading newspaper, and the builder of several educational institutions including Koryŏ University. After World War II he was active in Nationalist politics and was Vice-President of the Republic of Korea during 1950–1. (We owe this information to Gari K. Ledyard, private comm.)

[17] Jeon, STK, pp. 68–72 and Figs. 1.17, 3.11, 3.12, and 5.6. See also Jeon, 'Senki gyokkō (tenmon tokei) ni tsuite' 璇璣玉衡(天文時計)について (On armillary spheres with clockwork in the Yi Dynasty of Korea), *Kagakushi kenkyū* 科學史研究, 1962, *63*: 137–41; 'Yissi Chosŏn ŭi sige chejak sogo' 李氏朝鮮의時計製作小考 (A study of timekeeping instruments in the Yi Dynasty), *Hyangt'o sŏul* 鄕土서울, 1963, *17*: 49–114, pp. 102–11.

[18] (T. O. Robinson), 'A Korean 17th Century Armillary Clock' (notes on a lecture by J. H. Combridge on 27 November 1964), *Antiquarian Horology*, March 1965, *4*: 300–1.

then decided that the study was of such significance that it should become the basis for a monograph on the astronomical instruments of the early and middle Yi period which would also incorporate the passages previously translated from the *Sejong sillok* and the *Chŭngbo munhŏn pigo*.

There matters rested for several years. In 1973, Joseph Needham asked John Major if he would undertake the task of bringing the monograph to completion. Working together over the next few years, Major and Combridge revised the technical study of the Song Iyŏng / Yi Minch'ŏl instrument. Meanwhile, in July of 1974 Major visited Seoul, and again through the good offices of Jeon was kindly permitted by the authorities of the Koryŏ University Museum to examine the instrument closely. This allowed the answering of some technical questions that could not be resolved through an examination of the photographs. At about the same time, the authors agreed that the photographs selected to accompany the study would be easier to understand if they were augmented by a set of explanatory line-drawings.

Meanwhile, work proceeded on the revision of the earlier draft translations from the *Sejong sillok* and the *Chŭngbo munhŏn pigo*; and photographs of surviving parts of King Sejong's instruments, and of other instruments analogous to them, were assembled. As the technical details contained in the translations were understood with greater clarity, drawings and sketches of the instruments were produced.

With the revision of an article by Needham and Lu on an eighteenth-century astronomical screen, previously published in 1966 in *Physis*,[19] and with the writing of additional chapters to set our research in an appropriate historical framework, the work was brought to completion.

Throughout this long span of time, Gari K. Ledyard offered considerable further assistance, making numerous corrections to, and comments on, the draft translations and providing us with a detailed critique of a draft of the entire book. Similarly, Jeon Sang-woon freely supplied advice on questions of Korean history and technology, and furnished us with a number of the photographs used herein.

We wish to express our deep gratitude to Dr Ledyard, Dr Jeon, and the other colleagues and friends named above, without whose aid this work would never have been accomplished. In addition, thanks are due to Dr Nathan Sivin for much

[19] 'A Korean Astronomical Screen of the Mid-Eighteenth Century from the Royal Palace of the Yi Dynasty (Chosŏn Kingdom, 1392 to 1910)', *Physis*, 1966, *8*.2: 137–62.

helpful advice during the later stages of the work, to Dr David C. Major, who read a complete draft of the manuscript and made many helpful suggestions, and to Mr William Taylor for advice on drawings.

We are grateful to Mrs Katherine Lowe, Mrs Elizabeth Alexander, and Mrs Gail Patten for their patient and accurate work on the many drafts of the manuscript that have passed through their hands.

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