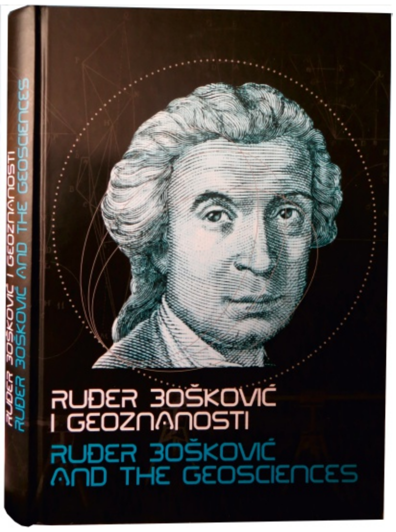
The monograph Ruđer Bošković i geoznanosti / Ruđer Bošković and the Geosciences



The monograph *Ruđer Bošković i geoznanosti / Ruđer Bošković and the Geosciences* was published at the begenning of 2016. The editor was Prof. Dr. Miljenko Lapaine, and the publishers were the Faculty of Geodesy of the Univeristy of Zagreb, State Geodetic Administration, and the Croatian Chamber of Chartered Geodetic Engineers. The book is A4 format, hardcover, contains 363 pages, all texts are in Croatian and English language, ISBN 978-953-6082-14-8.

This monograph, after a foreword and an editorial, begins with facsimiles of two of Bošković's early works, with Croatian and English translations: *De veterum argumentis pro telluris sphaericitate dissertatio* (*On the arguments of the ancients for the sphericity of the Earth*), 1739, and *Dissertatio de telluris figura* (*A dissertation on the shape of the Earth*), 1744, also published for the first time in 1739.

In the chapter headed *Ruđer Bošković and the Study of the Composition of the Earth*, Tomislav Malvić introduces the reader to Bošković's interest in the shape of the Earth. Of particular significance is the fact that Bošković determined that the rotational ellipsoid of the Earth was flattened at the poles, simultaneously confirming that the shape of the Earth was difficult to define and even more difficult to confirm by taking measurements. He introduced principles which later formed part of the theory of isostasy, and implied the compensation of shapes in the relief by the distribution of mass in the Earth's crust, from which it emerged that the crust had a lower boundary. Bošković also made a great contribution to the theory of forces and elementary particles. He thought the atom was the smallest structural particle of matter (a-tom), and he represented it by geometrical points, between which a force field acted. The field repelled at short distances and attracted at greater distances (in a space in the order of 10–15 m). These particles could be linked in systems of greater order, forming barions, atoms, molecules and crystals.

In the chapter headed *Bošković and the Theory of Isostasy*, Mario Brkić explains how Bošković's thoughts on the shape and composition of the Earth and the formation of the Earth's crust, the geodetic, astronomical and gravimetrical measurements which he took and his introduction of the concept of compensation, centuries before the creators of the theory of isostasy, identify him as a precursor and guiding star in new fields within geodesy and geophysics.

In the chapter headed *Ruđer Bošković and Astronomy*, Drago Špoljarić and Tatjana Kren describe Bošković's educational and teaching activities within the Jesuit educational system, where he lectured in astronomy. They explain the influence of his formal education, teaching activities and self-instruction (in Newton's scientific principles) on his astronomical research and dilemmas, his efforts on behalf of modern science, and the prevalence of peripatetic natural philosophy. His first scientific dissertations on astronomy are described, along with his development into a respected scientist and professor, and his later activities as a member of the Society of Jesus in the service of science. Astronomy is shown to be probably the key science which motivated and guided him in his scientific research. Bošković's research and achievements in theoretical and practical astronomy are also cited. The Observatory in Brera and its significance in Bošković's later life are described. His major work, *Philosophiae naturalis teoria* (A Theory of Natural Philosophy), is highlighted, along with a work which is crucial to an understanding of his research in astronomy, *Opera pertinentia ad opticam et astronomiam* (Works Pertaining to Optics and Astronomy).

Throughout the chapter headed *Bošković's Differential Formulae of Spherical Trigonometry* Miljenko Lapaine supports the claim which other authors have noted when writing about Bošković – he was not involved in mathematics for its own sake, but was regularly inspired by specific, practical problems in geodesy, astronomy, construction or other areas, which he frequently resolved by the application of mathematical laws. In this context, Bošković's interest in spherical trigonometry was directed towards its application in astronomy and geodesy. His first scientific contribution to

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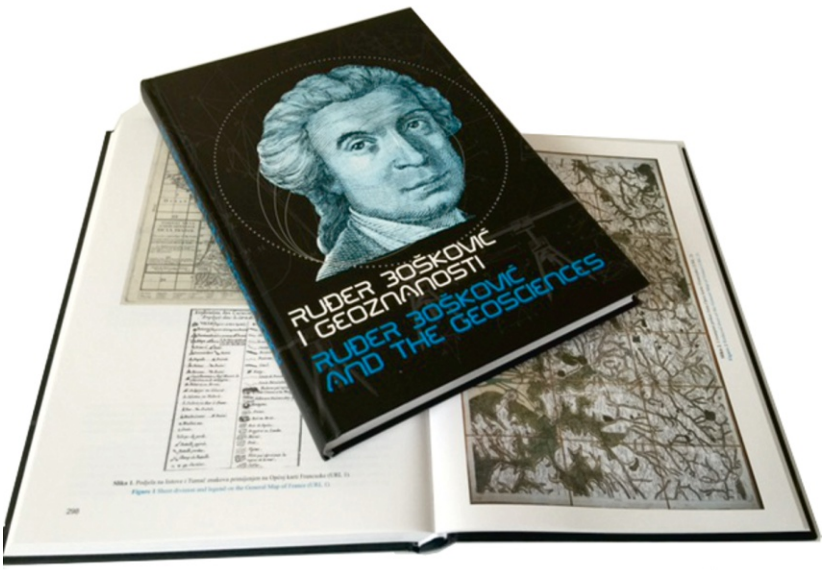
Monografija *Ruđer Bošković i geoznanosti / Ruđer Bošković* and the Geosciences objavljena je početkom 2016. godine. Urednik monografije je prof. dr. sc. Miljenko Lapaine, a izdavači Geodetski fakultet Sveučilišta u Zagrebu, Državna geodetska uprava i Hrvatska komora ovlaštenih inženjera geodezije. Knjiga je formata A4, tvrdo ukoričena, sadrži 363 stranice, svi tekstovi su na hrvatskom i engleskom jeziku. ISBN 978-953-6082-14-8.

Monografija nakon predgovora donosi dva Boškovićeva rana rada u obliku faksimila i u prijevodu na hrvatski i engleski jezik: *De veterum argumentis pro telluris sphaericitate dissertatio ...* (Rasprava o drevnim argumentima za zemljinu sferičnost) iz 1739. i *Dissertatio de telluris figura ...* (Rasprava o Zemljinu obliku), iz 1744., a prvi put objavljena također 1739.

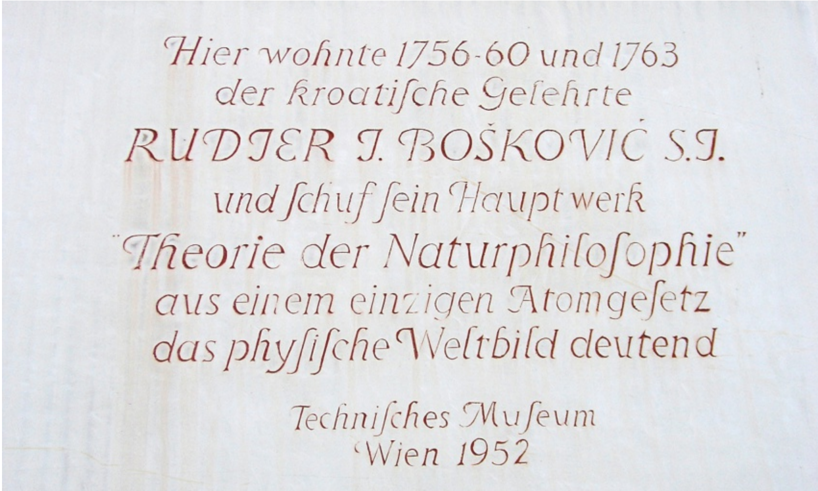
U poglavlju *Ruđer Bošković i izučavanje Zemljine građe* Tomislav Malvić uvodi čitatelja u Boškovićevo zanimanje za Zemljin oblik. Posebno je znakovito da je Bošković određivao spljoštenost Zemljina rotacijskog elipsoda, ali je uz to tvrdio da je Zemljin oblik zapravo teško definirati i još teže utvrditi mjerenjima. Uveo je principe kasnije obuhvaćene teorijom izostazije, koji su podrazumijevali kompenzaciju oblika u reljefu rasporedom masa u Zemljinoj kori, iz čega je proizlazilo da ta kora ima donju granicu. Veliki doprinos Bošković je dao u teoriji sila i elementarnih čestica. Atomom je smatrao najmanje gradbene čestice materije (a-tom), koje je predstavio geometrijskim točkama između kojih djeluje polje sila. Ono je odbojno na malim, a privlačno na većim udaljenostima (u prostoru reda veličine 10-15 m). Takve čestice mogu se povezivati u sustave većeg reda stvarajući barione, atome, molekule i kristale.

U poglavlju *Bošković i teorija izostazije* Mario Brkić objašnjava da zamisli o obliku i sastavu Zemlje, o nastanku Zemljine kore, poduzete geodetske, astronomske i gravimetrijske izmjere, uvođenje pojma kompenzacije stoljeće prije tvoraca teorija izostazije, Boškovića ustoličuju za prethodnika i putokaz u nova područja u geodeziji i geofizici.



Drago Špoljarić i Tatjana Kren u poglavlju *Ruđer Bošković i astronomija* opisuju Boškovićevo obrazovanje i nastavničku djelatnost u isusovačkom obrazovnom sustavu, u kojem je učio i astronomiju. Pokazan je utjecaj obrazovanja, nastavničke djelatnosti i samoobrazovanja (Newtonova znanstvena načela) na Boškovićeva astronomska istraživanja i dvojbe, borbe za modernu znanost i prevladavanje peripatetičke prirodne filozofije. Opisane su prve Boškovićeve znanstvene rasprave iz astronomije, razvoj u znanstvenog uglednika i profesora, te kasnije Boškovićevo djelovanje kao redovnika Družbe Isusove u službi znanosti. Pokazuje se da je astronomija vjerojatno ključna znanost koja ga je motivirala i vodila u znanstvenim istraživanjima. Navedeni su Boškovićeva istraživanja i dosezi u teorijskoj i praktičnoj astronomiji. Opisana je Zvjezdarnica u Breri i njezin značaj u kasnijem Boškovićevu životu. Istaknuto je njegovo kapitalno djelo Philosophiae naturalis teoria (Teorija prirodne filozofije), te ključno djelo za razumijevanje njegovih istraživanja u astronomiji *Opera pertinentia ad opticam et astronomiam* (Djela koja se odnose na optiku i astronomiju).

Kroz poglavlje Boškovićeve diferencijalne formule sferne trigonometrije kojem je autor Miljenko Lapaine provlači se tvrdnja koju su uočili i drugi autori pišući o Boškoviću: on se nije bavio matematikom radi matematike same, nego je redovito inspiriran konkretnim praktičnim problemima iz geodezije, astromonije, graditeljstva ili nekog drugog područja i rješavao ih najčešće primijenjujući matematičke zakonitosti. U tom



mathematics was the dissertation *Trigonometriae sphaericae constructio* (The Construction of Trigonometric Spheres) in 1737. In six propositions, he proposed a solution to the basic problems of spherical trigonometry, using a graphical construction. In his 1745 dissertation, *Trigonometria sphaerica* (Spherical Trigonometry), Bošković systematically analysed spherical trigonometry in twenty pages. In the first volume of his *Elementorium universae matheseos* (Elements of General Mathematics) in 1757, he included a chapter called *Trigonometry*, presenting the basics of plain and spherical trigonometry. The relations between the elements of a spherical or plain triangle are important when investigating measurement errors in astronomy and geodesy. Bošković studied the differential changes of the elements of a (spherical) triangle as part of his investigation of astronomical instruments, an activity which he initiated and carried out as director of the Observatory in Brera. This led him, in around 1770, to produce four basic formulae in which a differential change in one of the elements of any triangle (three sides and three angles) could be linked to differential changes in any three of the other five elements.

In the chapter headed *Bošković, Improver and Inventor of Geodetic, Astronomical and Optical Instruments*, Drago Špoljarić and Nikola Solarić describe Bošković's work in building new, and improving existing instruments, which he used for research and professional purposes. His inventions are listed and described, from his circular micrometer, geodetic stands and vitrometer, to his water-filled telescope. His improvements to geodetic measuring rods, quadrants, sectors, pendulum clocks and optic micrometers are also described.

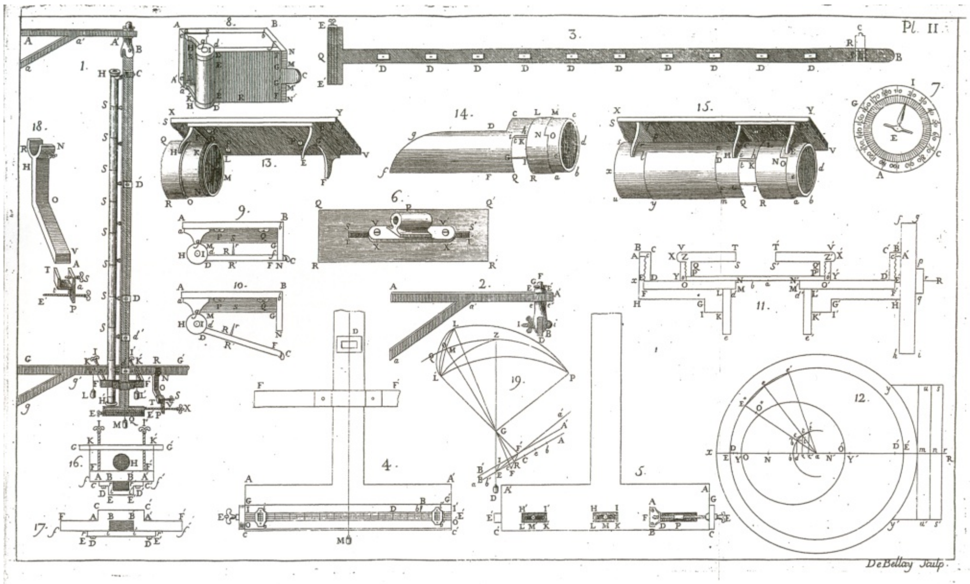
Interest in the Earth's shape and dimensions goes back to ancient times. In the introduction to their chapter *Bošković and Maire's Trigonometric Network for Determining the Lengths of Part of the Meridian Arc between Rome and Rimini*, Miljenko Solarić and Nikola Solarić provide an overview of how the Earth's dimensions have been measured throughout history, beginning with Eratosthenes' first measurements and ending with geodetic measurements in Lapland and Ecuador. Bošković was still a young man when the debate arose regarding whether the Earth was flattened at the poles or the Equator. So it is understandable that he was interested in determining the shape of the Earth. In his work *Dissertatio de telluris figura* (A Dissertation on the Shape of the Earth), Rome, 1739, Bošković expressed doubt that the Earth was a regular rotational ellipsoid and that all the meridians were equal in length. He therefore decided, with Christopher Maire, to measure part of the meridian arc between Rome and Rimini. In doing so, they made every effort to set up the best possible trigonometric chain of 11 triangles over a distance of 240 km, in order to determine the length of the arc of the meridian which passes through the top of the dome of St. Peter's in Rome. They paid the most attention to measuring precisely the lengths of the bases of the trigonometric chain. For the first time in history, the length of the bases were measured by setting measuring rods on tripods, constructed by Bošković according to his own original concept. As a result, they achieved a high degree of relative precision (1:300 000), considerably better that achieved by the French in measurements made in the same period. Furthermore, Bošković and Maire paid maximum attention to achieving a high degree of precision in measuring the angles in the triangles in the trigonometric chain. Bošković added special improvements to the quadrants he used to measure these angles, which increased their accuracy. For astronomical measurements, he had a sector made to measure the zenith distance of the stars. The results of determining the length of the meridian arc from Rome to Rimini were published in *De litteraria expeditione per pontificiam ditionem ad dimetiendos duos meridiani gradus et corrigendam mappam geographicam* (On the Scientific Expedition through the Papal States with the Aim of Measuring Two Degrees of the Meridian and Correcting the Geographical Map) in Rome in 1755. In it, he showed that the length of one degree of the meridian arc from Rome to Rimini, measured at the mean latitude of 43°, differed from the length of the Parisian meridian determined by Cassini III and De Lacaille at the mean latitude of 43°31', by as much as 69 toises. Theoretically, the difference caused by differences in latitudes should have been no more than 8 toises. In addition, Bošković analysed errors in the measurement-taking process and concluded that these could not have been great enough to result in a difference as large as 69 toises. Thus Bošković and Maire were the first to prove that the Earth was not a regular rotational ellipsoid, but that its shape was much more complex.

In the chapter called *Bošković and Maire's Map of the Papal States*, Ivka kontekstu je i Boškovićevo bavljenje sfernom trigonometrijom s ciljem njezine primjene u astronomiji i geodeziji. Njegov prvi znanstveni doprinos matematici bila je rasprava *Trigonometriae sphaericae constructio* (Konstrukcija sferne trigonometrije, 1737). U šest je propozicija ponudio rješenje za osnovne probleme sferne trigonometrije upotrijebivši grafičku konstrukciju. U radu *Trigonometria sphaerica* (Sferna trigonometrija, 1745) Bošković je na dvadesetak stranica sustavno raščlanio sfernu trigonometriju. I u prvom svesku svojih Elementorum universae matheseos (Elementi sveukupne matematike, 1754) Bošković donosi poglavlje *Trigonometrija* u kojem je dao osnove ravninske i sferne trigonometrije. Odnosi među elementima sfernog ili ravnog trokuta važni su pri ispitivanju pogrešaka mjerenja u astronomiji i geodeziji. Bošković je proučavao diferencijalne promjene elemenata (sfernog) trokuta u sklopu ispitivanja astronomskih instrumenata, što ga je zamislio i provodio kao ravnatelj Zvjezdarnice u Breri. Stoga je oko 1770. izveo je četiri osnovne formule u kojima se diferencijalna promjena jednoga od šest elemenata bilo kojega trokuta (triju stranica i triju kutova) povezuje s diferencijalnim promjenama bilo koja tri od pet ostalih elemenata.

Drago Špoljarić i Nikola Solarić u poglavlju *Bošković, usavršitelj i izumitelj geodetskih, astronomskih i optičkih instrumenata* opisuju Boškovićevu djelatnost pri konstrukciji novih i usavršavanju geodetskih, astronomskih i optičkih instrumenata kojima se služio u istraživačkim i stručnim zadaćama. Navedeni su i opisani Boškovićevi izumi od kružnog mikrometra, geodetskih stalaka, vitrometra do dalekozora napunjena vodom. Također su opisana njegova instrumentalna poboljšanja kod geodetske mjerne letve, kvadranta, sektora, ure njihalice i optičkoga mikrometra.

Već u starom vijeku postojalo je zanimanje za Zemljin oblik i njezine dimenzije. Stoga Miljenko Solarić i Nikola Solarić u uvodu poglavlja o *Boškovićevoj i Maireovoj trigonometrijskoj mreži pri određivanju duljine dijela meridijanskog luka Rim-Rimini* daju pregled određivanja Zemljinih dimenzija počevši od prvog Eratostenovog određivanja do geodetskih mjerenja u Lapland i u Ekvador. Bošković je bio mladi čovjek kad se razvila diskusija o tome je li Zemlja spljoštena na polovima ili na ekvatoru. Zato je razumljivo da ga je zanimalo određivanje Zemljina oblika. U radu *Dissertatio de Telluris Figura* (Rasprava o Zemljinu obliku), Rim, 1739. godine, Bošković je izrazio sumnju da je Zemlja pravilni rotacijski elipsoid i da su svi meridijani jednaki. Zato je odlučio da s Ch. Maireom započne s mjerenjem dijela meridijanskog luka Rim–Rimini. Pritom su nastojali postaviti što kvalitetniji trigonometrijski lanac od 11 trokuta na udaljenosti od 240 km, kako bi s pomoću njega odredili duljinu luka onoga meridijana koji prolazi vrhom kupole Sv. Petra u Rimu. Najveću pozornost posvetili su preciznosti mjerenja duljina baza trigonometrijskog toga lanca. Po prvi put u povijesti duljine baza mjerene su podizanjem mjernih letvi na posebne stalke, koje je po svojoj ideji konstruirao Bošković. Zahvaljujući tomu postigli su visoku relativnu točnost od 1:300 000, znatno bolju od one koju su u to doba postizali pri svojim mjerenjima Francuzi. Nadalje, Bošković i Maire posvetili su maksimalnu pozornost postizanju visoke preciznosti mjerenja kutova u trokutima trigonometrijskog lanca. Na kvadrante s pomoću koji se mjerilo, Bošković je postavio posebne dodatke s kojima je povećao točnost mjerenja kutova. Za astronomska mjerenja dao je izraditi i sektorski instrument za mjerenje zenitnih udaljenosti zvijezda. Rezultati određivanja duljine meridijanskog luka Rim-Rimini objavljeni su u djelu *De litteraria expeditione per pontificiam ditionem ad dimetiendos duos meridiani gradus et corrigendam mappam geographicam* (O znanstvenoj ekspediciji po Papinskoj državi sa svrhom izmjere dvaju stupnjeva meridijana i ispravljanja geografske karte) u Rimu, 1755. godine. U njemu su dokazali da se duljina jednoga stupnja meridijanskog luka Rim–Rimini izmjerenoga na srednjoj geografskoj širini od 43° razlikuje od duljine pariškog meridijana kako su ga odredili Cassini III. i De la Caille na srednjoj geografskoj širini od 43°31' za čak 69 toaza. Teoretski ta razlika uzrokovana razlikama u geografskim širinama mogla je biti svega 8 toaza. Osim toga Bošković je analizirao i pogreške u izvođenju mjerenja te je došao do zaključka da one nisu mogle biti tako velike da bi razlika iznosila 69 toaza. Na taj način Bošković i Maire su prvi dokazali da Zemlja nije pravilni rotacijski elipsoid, nego da je njezin oblik puno složeniji.

Ivka Kljajić i Miljenko Lapaine u poglavlju *Boškovićeva i Maireova karta Papinske Države* detaljno istražuju tu kartu (Nuova carta geografica dello Stato Ecclesiastico) što ju je 1755. izradio Christopher Maire na temelju mjerenja provedenih s Ruđerom Josi-



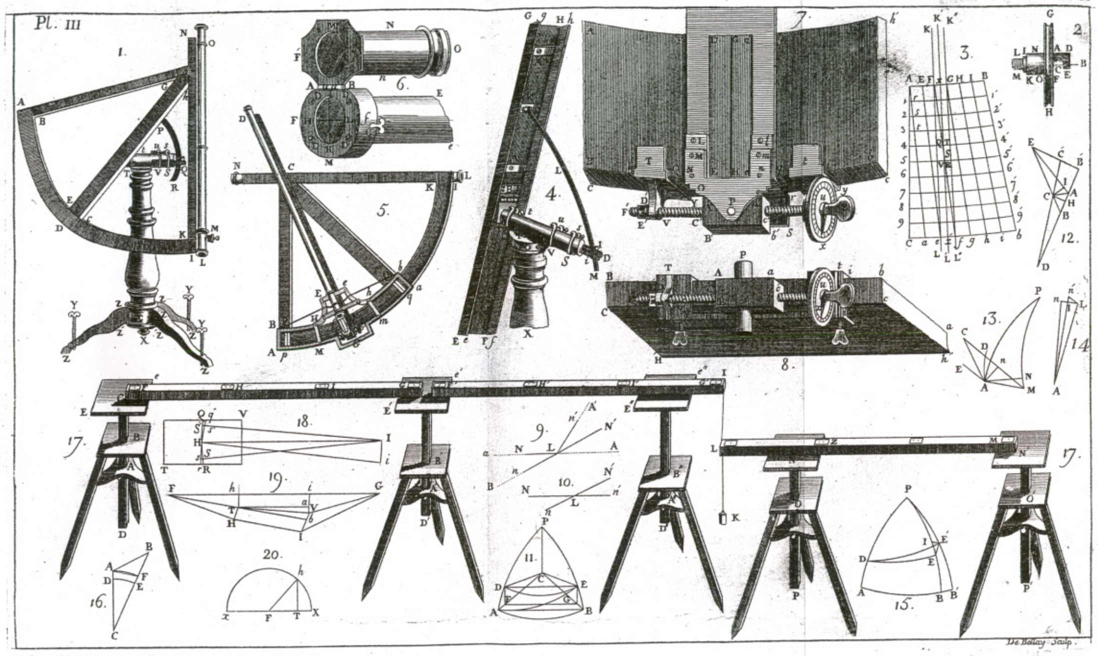
Kljajić and Miljenko Lapaine research and describe in detail the map entitled *Nuova carta geografica dello Stato Ecclesiastico* produced by Christopher Maire in 1755, based on the measurements he took with Ruđer Bošković. This map served as the source for a later version, the *Carte de l'État de l'Église*, published in 1770 in a work entitled *Voyage astronomique et géographique, dans l'État de l'Église*, which is also described in detail in this chapter. The dedication to Pope Benedict XIV in the cartouche of this 1775 map and explanatory texts from the cartouches of both maps are reproduced in their original form, i.e. in Italian and French, with translations in Croatian and English. Details are provided of copies of the 1755 map of the Papal States, which are today housed in different institutions, and details of similar maps produced using Bošković and Maire's measurements in the Papal States as a basis. There is also a biography of Christopher Maire, Bošković's companion and colleague during his astronomical and geodetic research in the Papal States between 1750 and 1753.

Robert Župan, Vesna Poslončec-Petrić and Stanislav Frangeš claim that Bošković's cartographic work can be divided into three areas, in the chapter entitled *Maps in Hydrotechnical Expert Opinions by Ruđer Bošković*. The first is the direct result of his measurements of the meridian arc between Rome and Rimini and the related production of the map of the Papal States. The second area includes maps which he used when travelling, about which nothing has so far been discovered, even today. The third area covers his hydrotechnical expert opinions, for which he also used maps. They form the subject of this chapter. Maps helped Bošković in his perception of areas of interest, and in his spatial analyses, proposals and conclusions regarding the installation of canals to solve the problem of flooding in a certain area, caused by a river overflowing its banks. Here, a brief overview is given of 18th century cartography, in order gain a better notionof the level of cartography and cartographic knowledge at the time, and the means by which maps were then produced.

The chapter entitled *Geographical Aspects of the Work of Ruđer Josip Bošković* by Josip Faričić makes the point that today, Bošković's work in determining the dimensions of the Earth and its shape, and his discoveries in the fields of isostasy, tidal movements and other phenomena, are considered major achievements in the fields of geodesy, geophysics and geology, although in his day, problems in these fields were tackled within the disciplines of geography and astronomy. In the light of contextualising Bošković's work in the historical period in which he conducted his research, it would be appropriate to consider him also as a geographer, alongside all the other scientific attributes which have so far been bestowed upon him. In any case, Bošković was an ardent traveller and scientist, who studied carefully the places in which he carried out his studies and through which he passed. It is surely impossible to overlook the geographical basis of his wide hydrotechnical expertise, or his keen observations on geographical features in the considerable part of Europe through which he travelled.

Martina Triplat Horvat and Ivan Razumović provide a historical overview of different types of measurements, highlighting the method of adjustments, in the chapter entitled *Bošklović's Method of Adjustment*. The first method of adjustment, invented by Bošković, is shown in detail, along with its further development and application. There is an analytical presentation of the method according to Laplace's elaboration of the method. Adjustments are implemented, by the application of a geometric and analytical form of Bošković's method, on examples of five and nine measured degrees of the meridian, and also based on information taken from Bošković's source texts. The results achieved are compared with those shown in Bošković's works. Finally, there are short descriptions of the position and potential application of Bošković's method of adjustment today.

Miljenko Lapaine



pom Boškovićem. Ta je karta poslužila kao izvornik kasnijoj inačici *Carte de l'État de l'Église* objavljenoj 1770. u djelu *Voyage astronomique et geographique, dans l'État de l'Église ...* koja je također detaljno opisana. Posveta papi Benediktu XIV. što se nalazi u kartuši karte iz 1755. i tekstovi s objašnjenjima iz kartuša obiju karata, objavljuju se u izvornom obliku, na talijanskom, odnosno francuskom jeziku te u prijevodu na hrvatski jezik. Dani su podaci o primjercima karte Papinske Države iz 1755. što se čuvaju u pojedinim institucijama te podaci o srodnim kartama izrađenim na osnovi Boškovićevih i Maireovih mjerenja provedenih po Papinskoj Državi. Osim toga, donosi se i životopis Christophera Mairea, Boškovićeva pratitelja i suradnika na astronomsko-geodetskim radovima u Papinskoj Državi od 1750. do 1753. godine.

Robert Župan, Vesna Poslončec-Petrić i Stanislav Frangeš u poglavlju *Karte uz hidrotehničke ekspertize Ruđera Boškovića* smatraju da bi se Boškovićev kartografski rad mogao podijeliti na tri područja. Ponajprije to je izravan rezultat njegove izmjere duljine luka meridijana od Rima do Riminija i s tim u vezi izrada karte Papinske države. Drugo su karte kojima se služio pri svojim putovanjima, a o čemu se do danas ništa ne zna. Treće područje su njegove hidrotehničke ekspertize pri kojima se također služio kartama. O tim kartama riječ je u ovome poglavlju. Karte Boškoviću pomažu za percepciju područja od interesa, kao i za potrebe prostornih analiza te prijedloge i zaključke o izvođenju kanala i rješavanju poplava na zadanom području pri izlijevanju rijeka iz korita. Uz to ukratko je prikazana kartografija 18. stoljeća zbog lakše predodžbe razine kartografije i kartografskog znanja toga doba te načina izrade karata.

U poglavlju pod nazivom *Geografski aspekti djelovanja Ruđera Josipa Boškovića* autor Josip Faričić razmatra geografske aspekte djelovanja Josipa Ruđera Boškovića. Premda se danas njegova ostvarenja vezana uz određivanje dimenzije Zemlje, njegove rasprave o obliku Zemlje, o izostaziji, plimi i oseki te dr. smatraju postignućima na polju geodezije, geofizike i geologije, u njegovo su se doba ti problemi rješavali u okviru geografije i astronomije. Sukladno kontekstualizaciji Boškovićeva djela u povijesnom razdoblju u kojem je istraživao, bilo bi dobro Boškovića, uz sve njegove do sada isticane znanstvene atribucije, smatrati i geografom. Uostalom, Bošković je bio zainteresiran putnik i znanstvenik koji je pažljivo proučavao prostor u kojem je znanstveno djelovao i kroz koji je prolazio. Zacijelo nije moguće previdjeti geografsku osnovu njegovih brojnih hidrotehničkih ekspertiza kao i oštroumne opservacije o geografskim obilježjima velikog dijela Europe kojim je proputovao.

Ivan Razumović i Martina Triplat Horvat u poglavlju *Boškovićeva metoda izjednačenja* prikazuju povijesni pregled obrade različitih vrsta mjerenja s naglaskom na metode izjednačenja. Detaljno je prikazana prva metoda izjednačenja, koju je osmislio Bošković, te njezin daljnji razvoj i primjena. Objašnjeni su uvjeti koji moraju biti zadovoljeni da bi se neka mjerenja mogla izjednačiti po Boškovićevoj metodi. Dan je analitički prikaz metode sukladan Laplaceovoj razradi metode. Provedena su izjednačenja, primjenom geometrijskog i analitičkog oblika Boškovićeve metode, na primjerima za pet i devet mjerenih meridijanskih stupnjeva. Mjerenja korištena za računanje preuzeta su iz Boškovićevih izvornika. Dobiveni rezultati uspoređeni su s onima koji su iskazani u Boškovićevim djelima. Na kraju su još ukratko opisani današnji položaj i primjena Boškovićeve metode.

Miljenko Lapaine ■