To His Excellency LEVI LINCOLN, Governor of the Commonwealth of Massachusetts.

SIR,

The Commonwealth of Massachusetts having resolved, that surveys of its territory should be made "on trigonometrical principles, and astronomical observations, for the purpose of making a correct map thereof;" and those surveys having been commenced, it has been deemed requisite, that a report of the progress therein should be made to His Excellency the Governor of this Commonwealth, under whose immediate direction and control they are to be made.

Operations on trigonometrical principles, serve not only for the purpose of making an accurate map of a State, or Country, but for many other valuable purposes, civil, military, and scientific.

Surveys of this kind have been made only by the most enlightened nations of Europe, and have served to mark the progress of civilization, the extension of knowledge,
the state of the sciences, and a general desire in the community for correct and useful information.

In order to show the great accuracy of which such surveys are susceptible, and the different purposes to which they have been applied, it has been thought necessary, that a short account should be given of some of them, which have heretofore been made on the same or similar principles.

It was not till late in the last century, that France and England made the first surveys of their kingdoms on trigonometrical principles. As science advanced, and commerce and internal intercourse increased, it became necessary to determine, with greater accuracy, the position of distant places. It was then found, that surveys, made in the manner of common land measuring, were very defective, when applied to the measurement of extensive portions of the surface of the earth. In common land surveying, the areas are generally very small, and the measures are generally very small, and the measures are considered as having been made on horizontal plains. These surveys seldom exceed a mile in extent, in which distance the curvature of the earth, being only eight inches, does not materially affect them; but, when it is considered, that this curvature increases in the very rapid ratio of the square of the distance, and that, too, in every direction from the point of commencement, it is easy to perceive, that extensive measures, made on a surface nearly spherical, and projected on a plane tangent thereto, must be very erroneous.

The first regular operation on trigonometrical principles, worthy of notice, is that, which was instituted in France, by the Academy of Sciences, to determine the magnitude of the earth. The philosophers of that learn-
ed institution, for this purpose, made the judicious selec-
tion of that able and practical geometer, Picard, who, 
with great care and precision, measured, trigonometri-
cally, from an accurate base line, an arc of the meridian, 
from Paris to Amiens; by this process and by astronomi-
cal observations, made at each extremity of the arc, he 
obtained the value of one degree of the great circle of 
the meridian, and consequently the solution of this inter-
esting and useful problem, which had so long occu-
pied the attention of the greatest geometers and astron-
omers of the learned world.

The next operation of this kind, was performed by 
Cassini, for the same purpose, who continued the triangu-
lation from Picard’s southerly to Perpignan, a distance 
of more than three hundred and fifty miles, where he 
measured a base of verification, which was found to 
coincide extremely near with the line deduced from the 
calculations made of the triangles from the base of de-
parture. This operation afforded much additional data 
for the determination of the magnitude of the earth, and 
proved the accuracy of Picard’s performance.

Subsequently, the younger Cassini measured an arc 
of the meridian from Paris to Dunkirk, by a system of 
triangles, when he ran another line of verification, the 
result of which proved equally satisfactory.

Cassini De Thury and la Caille, re-measured the tri-
angles of Picard and the two Cassini’s, with the greatest 
possible care, for the purpose of verifying their measures 
of the arc of the meridian.

To advance the art of navigation, and to facilitate the 
operations of commerce, it became necessary, that the 
figure of the earth should be accurately determined for 
this purpose. The French Geometers, Condamini, Go-
din, and Boquer, repaired to the city of Quito, in South America, then on the plains of . They measured and calculated, with the greatest accuracy, a true geodesic base line, from which they obtained, trigonometrically, the value of several degrees on an arc of the meridian, near the equator. At the same time, Maupertius, Clairault, and Mouier, measured another arc of the meridian, near the Gulf of Bothnia, in the 66th degree of north latitude, for the same purpose.

The triangulation, conducted by Cassini, for measuring a degree of a great circle, perpendicular to the meridian, was afterwards carried over the whole territory of France, which gave a greater degree of accuracy to its geography, than had ever been attained in any other country.

When the project was formed to ascertain and establish a standard of measure in France, on a consultation of the philosophers of that country, among whom were the truly scientific La Place, and the justly celebrated Mouze, (founder of the Polytechnic School, and father of descriptive geometry,) they recommended the measurement of an arc of the meridian, trigonometrically, in preference to every other method proposed, to effect so desirable an object. The first geometers of that age accomplished this delicate operation, and thereby established the unit of measure for that kingdom.

The first impulse to the trigonometrical survey of the kingdom of Great Britain, was doubtless given by the French geometer Cassini de Thury, by a proposition to the British government to determine, on trigonometrical principles, the relative position of the two great observatories of Greenwich and Paris, that thereby a just
coincidence might be established in the astronomical observations made at both places.

The British Government, seeing the great utility of this measure, in affording facilities to commerce and navigation, immediately made ample appropriations for this purpose, and availed itself of the practical talents and skill of General Roy, who was forthwith appointed to this service, and commenced his operations, by measuring, with great care and exactitude, a base line, of about five miles, on Hounslow heath, from which he continued his triangulation to the eastern coast of the kingdom, and extended it across the British Channel, to certain and known station points on the coast of France.

Cassini, Mechain, and Le Gendre, members of the French Academy of Sciences, were appointed in France, to continue this system of triangles to a station point, near Dunkirk, the relative position of which, with the observatory at Paris, had been previously ascertained. They also extended their triangles across the British Channel, to the station points of General Roy, and although these operations were performed by the French philosophers with a repeating circle of Borda, centesimally divided, and by General Roy with the English theodolite of Ramsden, sexagesimally divided, they were found to agree with a precision truly astonishing; and the relative position of the two observatories, as found trigonometrically, differed but a very small quantity from that deduced from the observations of the astronomer royal in England.

The surveys of the whole kingdom of Great Britain, made on similar principles, after the death of General Roy, were successfully conducted and completed by
Colonel William Mudge, a gentleman of high scientific acquirements, and great practical skill in geodesic operations.

Most of those splendid and accurate surveys have been published in England, and maps of them deposited in the archives of the Department of State, in the City of Washington.

Thus we find, that a practical application of the exact sciences has been made to determine the figure and magnitude of the earth, the true position of terrestrial objects, a standard of linear measure, and for performing the most accurate surveys of extensive portions of the surface of the earth.

To form a correct idea of the progress already made in the trigonometrical survey of the territory of this State, it may, perhaps, be best to give a brief description of the manner of making such surveys, particularly as only two of them have ever been attempted in America. The first, was the survey of the coast of the United States, by Professor F. R. Hassler, which was discontinued immediately after its commencement. The other, was that of the State of Rhode Island, which has been but recently completed, and of which, there has not, as yet, been any description given.

The first operation in making surveys on these principles, is that of measuring a base line, technically so called, in consequence of its being the basis on which all the subsequent operations depend, it must therefore be made in the most accurate manner.

This line is formed by the intersection of a plane perpendicular to the horizon, with the surface of a sphere, whose centre is at the centre of the earth. Its exact measurement, is one of the most difficult operations in
practical geometry, on the completion of which, it must be reduced, by a simple formula, to a plane of comparison, or to the level of the sea, when it becomes a true geodesic line, from which the calculations of the lengths of all the other lines are determined. The *tracery* of this line should be made on a terrestrial plain, of great extent, free from obstructions, and as level as possible. Its position, with respect to the meridian, may be disregarded, but it should be such, as to give the most commanding view of distant and elevated objects in every direction from it. Its length should be such, that the most distant station point, when seen from its extremities, will appear under angles of sixty degrees with the line, and it should never exceed a length, which would cause said station points to appear under angles less than thirty degrees.

These are among the many prerequisites of this line, the modus operandi in its ultimate tracery and measurement, with the apparatus necessary for its performance, may be detailed, if necessary, in a subsequent report.

The second operation is that of Triangulation. This consists in forming, and well arranging a system of triangles extending in every direction over the whole surface of the country to be surveyed. These triangles should be as large as possible, and as nearly equilateral, as the face of the country, and other circumstances will permit. Every angle of these *primitive triangles* must be carefully observed, and frequently repeated. The points made by the intersection of their sides, are called station points, and should be designated by signals placed in proper positions, which can easily be erected and removed, so that by placing the instrument over the centre of the station, the calculation of the reduction
for eccentricity may be avoided, and, by replacing the
signal, it will again serve as a station point, for many
other triangles extending in different directions. This
triangulation should commence at the Base line, at the
extremities of which, the angles between the first sta-
tion point and the Base must be accurately observed.
These two angles, together with the exact measure of
the Base are considered in theory as sufficient data to
determine the other two sides, and the remaining angle,
but in practice, the angle opposite the base should also
be observed, that the coincidence of the calculated an-
gle with that obtained by actual observation may serve
as a verification of the angles at base, and the lines de-
duced from them: for the sides opposite the angles at
the Base, will become the bases of the secondary trian-
gles, which are formed within the primitive. The an-
gles opposite these secondary bases may rest on any
prominent and well-defined object: two angles of these
secondary triangles must always be observed, and the
third also, when it is convenient, or a verification of the
work requires it. Every station in the primitive, and in
the secondary series, must be considered and used, as
points of continual reference and verification in all the
subordinate detail surveys.

It is easy to be perceived, that the undulating face of
the country will cause the station points to be of very
different elevations, and the triangles resting on them
to be contained in planes inclined to the horizon in al-
most every direction. If the angles of these triangles
are observed with an instrument, whose plane must be
made to coincide with these inclined planes, it is evi-
dent that the true horizontal angle cannot be obtained,
and the sides calculated from such angles will be erroneous.

As every triangle taken in this manner, must be reduced to a horizontal plane, it will require much intricate and tedious calculation, which may cause an error, but when the angles are observed with an instrument, whose plane is always placed parallel to the horizon, this computation becomes unnecessary, and the risk of committing an error thereby avoided, for we thus obtain the inclination of the planes, which form the sides of triangular pyramids, whose apexes are at the centre of the earth. The intersections of these planes form the lines, which contain the station points, the projections of which are determined by the intersections of said lines with a sphere, whose centre is at the apex of the pyramid, and whose surface is at the level of the sea: but because the line, which passes through the centre of the instrument perpendicular to the horizon, at one station, is not parallel to the same line at the other stations, the sum of the three angles will exceed two right angles. And as few instruments are capable of giving the excess, it may be found by computation, and should be noticed in all geodesic calculations.

In consequence of the projections of the station points, being made on a surface nearly spherical, and which, from its nature cannot be developed, they must be transferred to the surface of a cone, whose element is parallel to the cotangent of the middle latitude of the country to be surveyed, and which intersects the surface of the earth at two points, equidistant from the parallels which bound the country, and the middle latitude thereof. The third operation is called Orientation; by this process the azimuths or angles, which
some of the sides of the primitive triangles make with the true meridian, which passes through them, is determined by observation of the Polar Star, or otherwise. This gives the true position of every other line and station point throughout the survey. It is however requisite, that the latitudes and longitudes of a number of points be ascertained as accurately as possible by astronomical observations.

At any convenient time, either prior or subsequent to any of these operations, a line of verification may be located at a distance from the base line proportioned to the extent of the survey, and as far as other circumstances will permit. It must be measured in the same manner, with as much care and accuracy as the base itself. This line of verification should form the side of one of the triangles in the great concatenation of primitive triangles. Its just coincidence with the length of the line found by computation, proves the accuracy of all the previous operations.

This brief sketch of the manner of making surveys on trigonometrical principles will perhaps be sufficient for the purpose intended.

With respect to the surveys of the territory of this Commonwealth, I must remark, that they were not undertaken till late in the last season, and then being unprovided with any instruments for the triangulation, or apparatus for measuring the base line, or even a standard of linear measure, their procurement has necessarily caused some delay; the time expended in this business, and the expenses attending it, have been amply accounted for in a former communication. After procuring the standard of measure, and the instruments from the general government, and while the base
measuring apparatus was constructing, the locality of a base line was sought for, and, by the directions of your Excellency, the plains on the Connecticut River, above Northampton, in this State, were examined with a view to this purpose. After several essay lines had been measured on these plains, an excellent locality for a base line was obtained, the proximate tracery of which was made on that fine alluvial deposit on the west bank of the Connecticut river, commencing at Long hill, in Deerfield, and extending nearly a south course about ten miles through the towns of Whately and Hatfield, to the great bend of the Connecticut river, westward of Hadley ferry. In this distance the line will cross only a small branch of Bloody brook, in Deerfield, and the main stream of Mill creek, in Hatfield, but without crossing the latter, the base will exceed eight miles, and will differ but very little in level in its whole length.

At the extremities of this line, and at several points upon it, the view eastward is very extensive, the hills east of Amherst College, in the towns of Pelham and Shutesbury, afford many fine positions for station points at distances of twelve and fifteen miles.

Mount Toby, in the northeast, and Mount Holyoke, in the southeast, present other points equally well situated for stations of the secondary triangles.

The view west of the base, is somewhat less extensive. The hills of Whately approach the line near its centre, but the high lands of Williamsburg, at the distance of four or five miles, offer several good points. In the northwest, the mountains in Conway, and in the southwest, the hills of Westhampton will give suitable points to connect with the Green Mountain range.
along the eastern boundary of Berkshire, and with the Hoosack and Saddle-back mountains, in the north; these again will connect with the Hancock range, the Iaconic and Mount Washington on the western confines of the State.

Observations made to the eastward of the Connecticut river are more limited, being principally confined to the northern part of the counties of Franklin, Hampshire and Worcester, a sufficient number, however, have been made to warrant the opinion, that a very advantageous disposition may be made of the primitive triangles to connect in the best manner the greatest number of the most prominent points, from the Wachusett, in Princetown, to the Blue hills, in Milton, and thence along the whole line of sea coast, including Nantucket, and Elizabeth Islands.

The quadrilateral formed by the first triangles made on each side of the base, will give a diagonal line transverse to it, of nearly twenty miles in extent, making a fine secondary base, on the south side of which an extensive triangle may be formed, having its vertical angle on the summit of Mount Tom, and on the north of this diagonal, another triangle can be had, whose angle opposite the base may rest on the top of Mount Grace, or on the apex of a conical mountain near the northern boundary of the State; from these points the Grand Monadnock, the Wachusett, and the heights of Belchertown, Leicester, and Ashburnham, are very conspicuous, and favorably situated.

The height of several points on Miller's river above the level of the Sea, having been obtained by Col. Baldwin, in his survey for a canal from Boston to Albany, a set of levels from thence to the base line will
not be necessary, for from the well known accuracy of this excellent Engineer, it will not be taken as a mere assumption to consider his levels as affording established points from which to determine the height of the base above the level of the sea, which being found, its ultimate reduction to a true geodesic line is easily calculated. These and many other levels will afford points of reference, for the heights of the stations, and of verification for the allowance made for refraction in taking their zenith distances.

The exact height of the stations should be determined and carefully preserved, for they are points, from which can be ascertained the difference of level of places, the quantity of lockage for canals, or inclination for rail roads, and for many other purposes of internal improvement, and which will prevent the expense of leveling, from the sea coast to any point in the interior. These stations, in a military point of view, may be used to determine the points of telegraphic communication, and for other purposes, and if the triangulation be properly conducted, it will furnish additional data to determine the true figure of the earth.

Permit me only to add, that the apparatus for the tracery and measurement of the base, has been constructed wholly within this Commonwealth, is fully completed, and now on the line, together with all the instruments at present necessary for the performance of the work.

The field operations for the season are already commenced, with a favorable prospect for their steady prosecution.

From the peculiar nature of this work, from its commencement to the present time, I am happy to state,
that a greater progress has been made therein, than could have been reasonably expected.

The great interest taken in this survey, by your Excellency, and the solicitude so frequently and so earnestly expressed, for its advancement, have been met by corresponding interest, unremitting exertions, and consequent success.

I have the honor to be, Sir,
Very respectfully,
Your Obedient Servant,

JAMES STEVENS,
Civil Engineer.

Boston, May 1, 1831.