Properties of Portolan Charts

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I have an interest in the structure of these old charts.

Here are some of the older ones,
followed by an analysis of one that is over 500 years old.

Carte Pisane

Circa 1290 AD (Biblioteque Nationale Paris)

1456 Portolan Chart

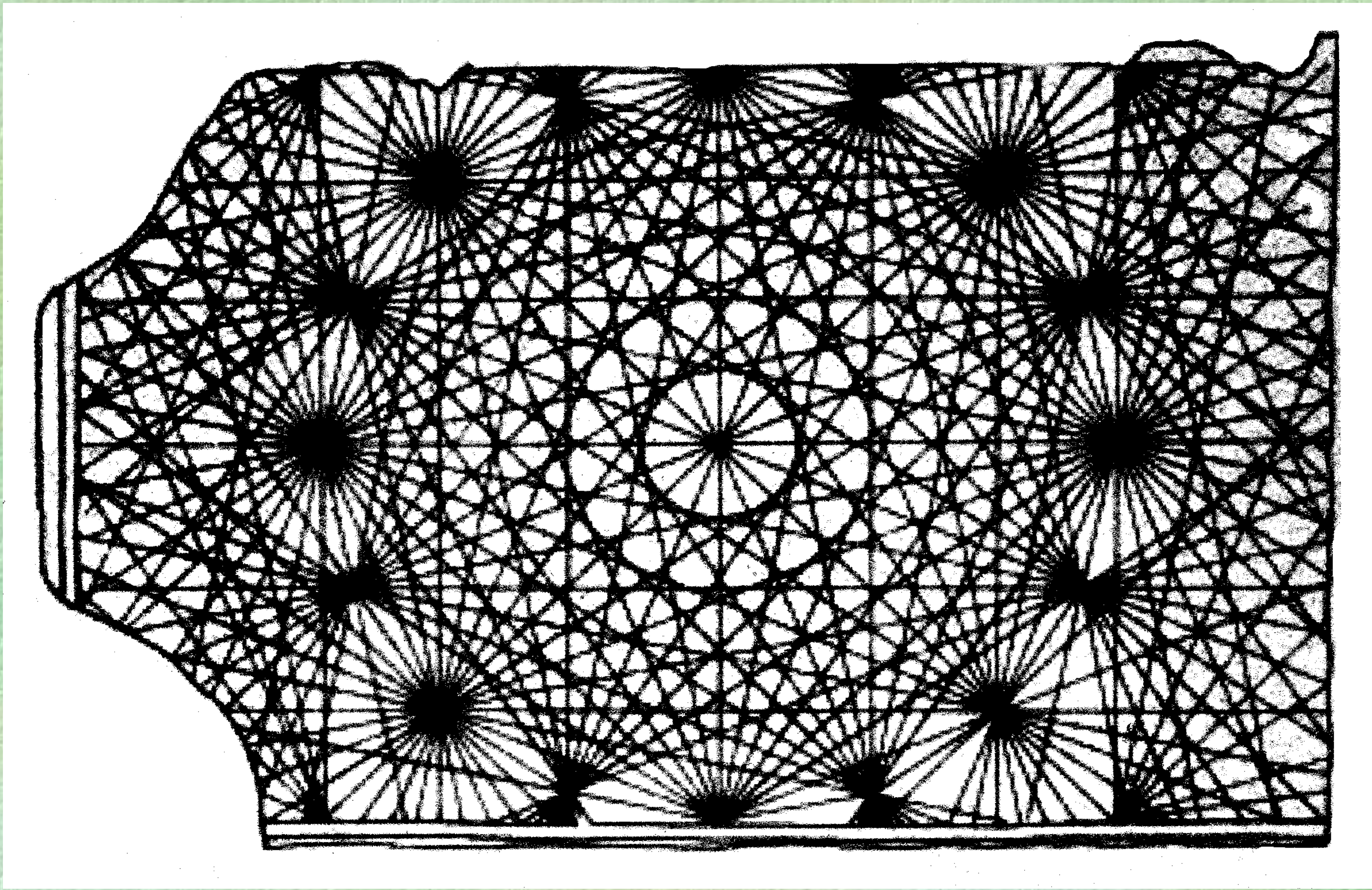
Benincasa Portolan Chart

1482 (Before Columbus)

Courtesy of R. Pflederer

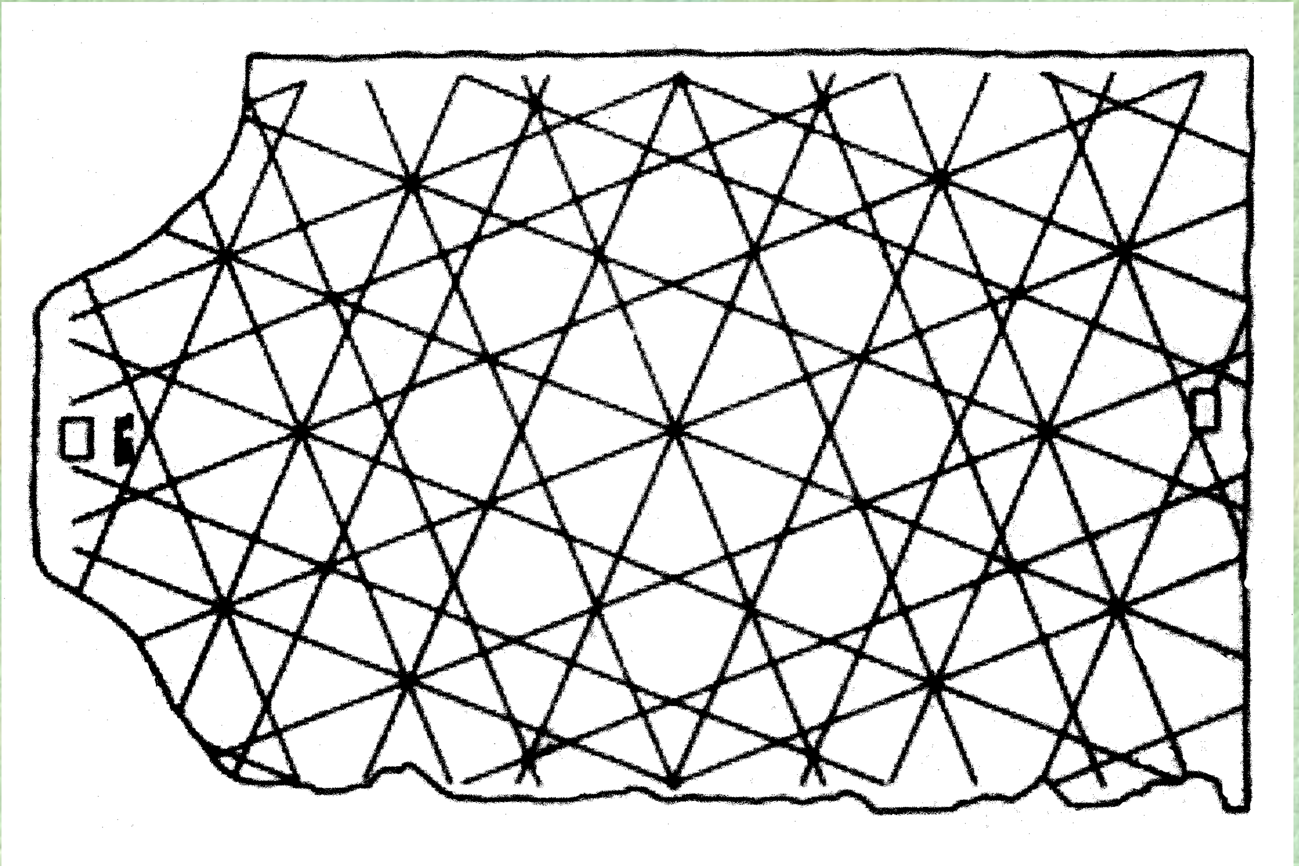
The "compas rose" as on most charts of the time

Over-emphasized



The backside

On some charts



What projection is used for these portolan charts?

Thus far proposed have been:

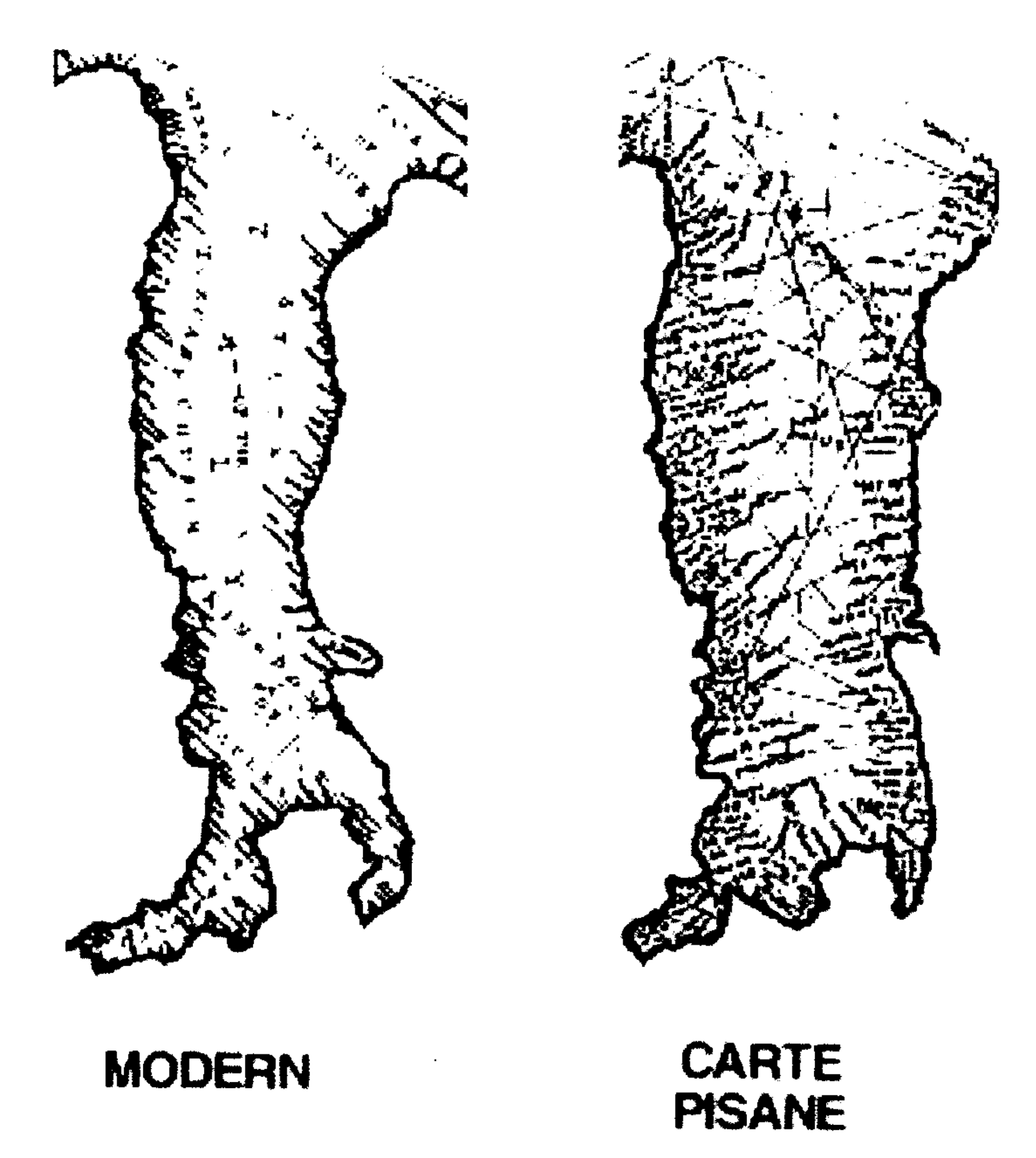
None (Eckert, Nordenskiold, and others)
The azimuthal equidistant (Fiorini)
The oblique stereographic (several times)
An oblique conformal conic
The oblique Mercator (Clos-Arceduc, Tobler)
An empirical projection (Lanman, Tobler)

Dr. Lanman plotted these locations using old sailing directions (portolani)

from his 1987 monograph

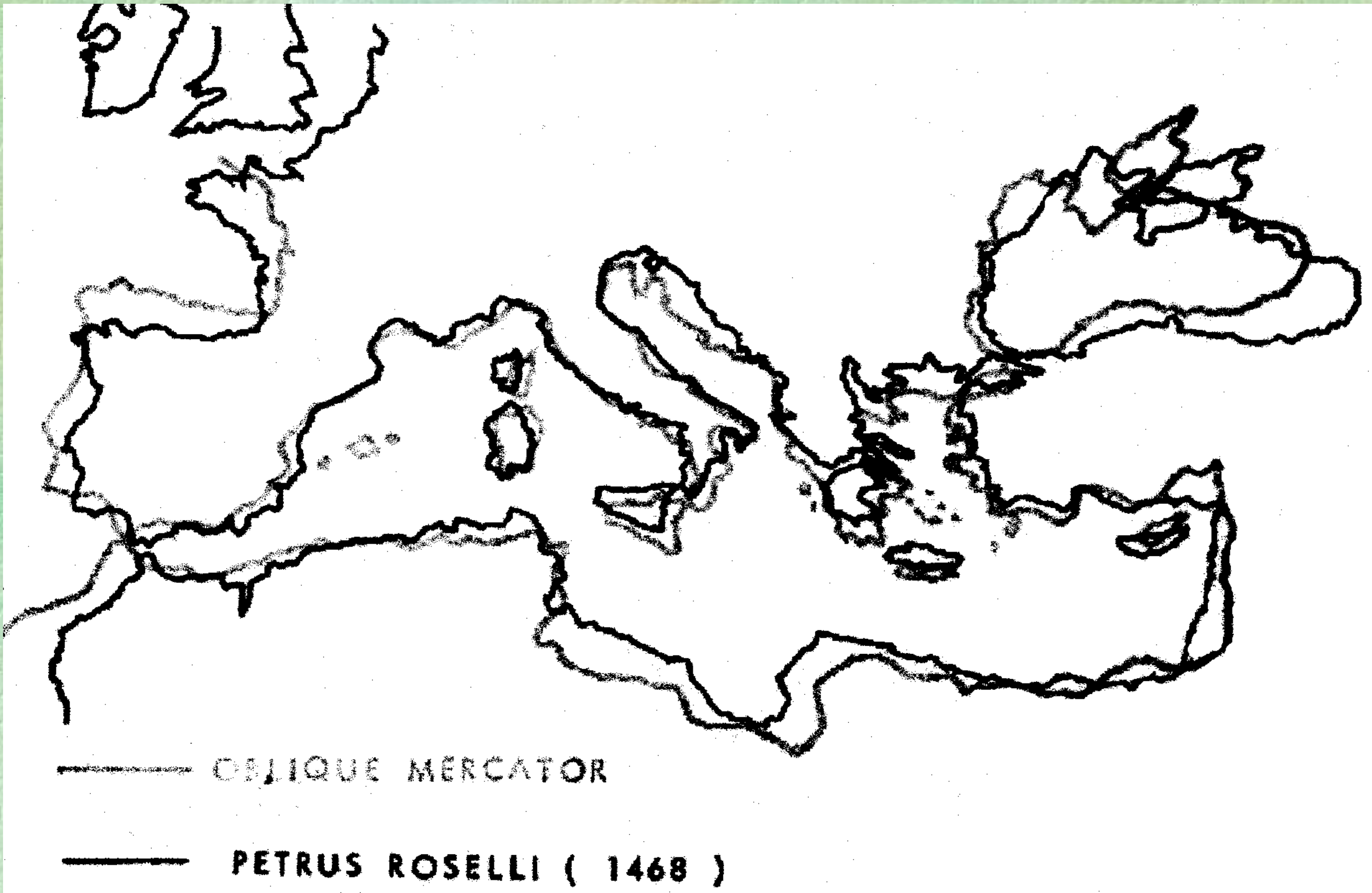
A comparison of Italy by Dr. Lanman

Modern and Carte Pisane from ~ 1290



A portolan in relation to an oblique Mercator

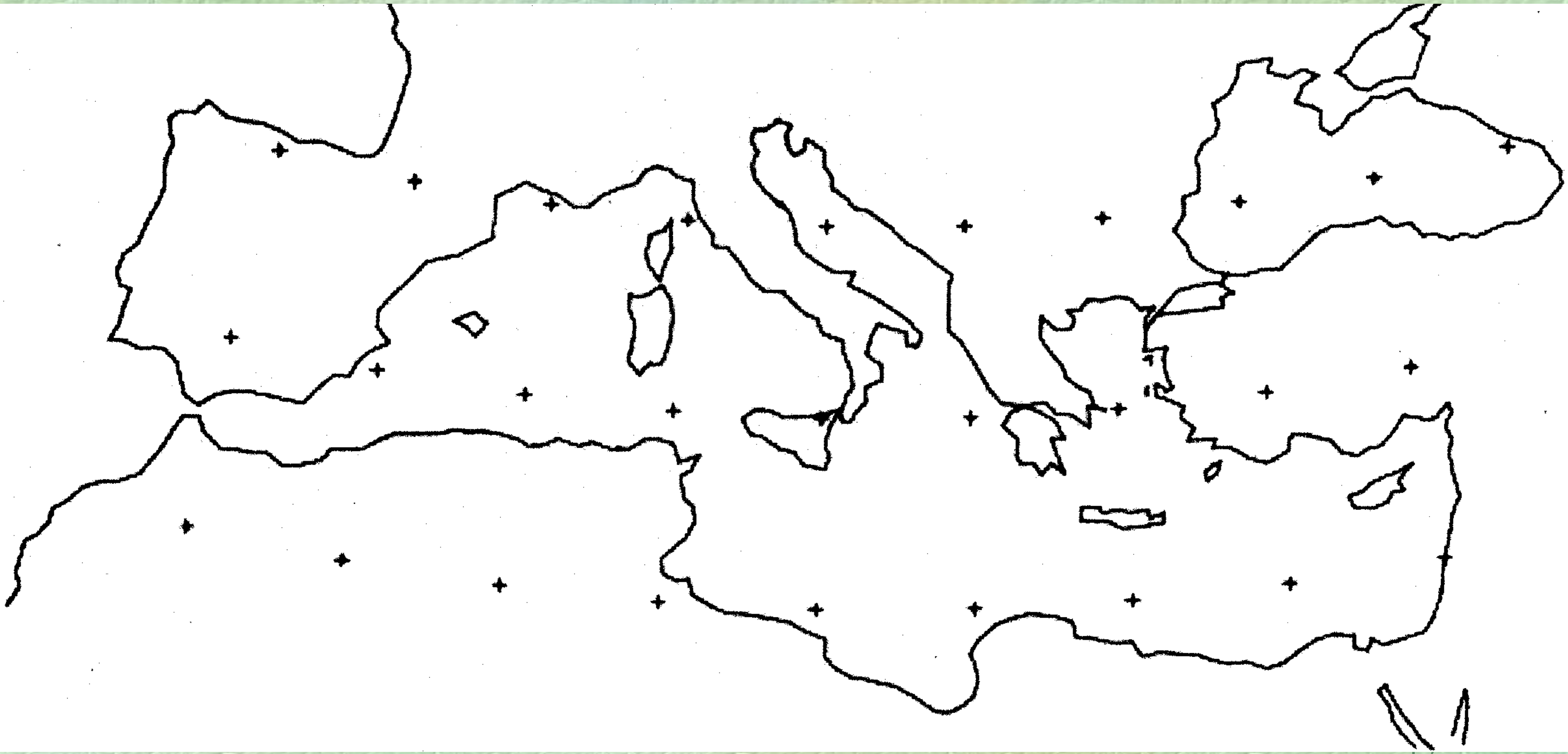
after Tobler (1966)



Empirical Map Projection

Preserving loxodromic distances

By Tobler (1977)



Which projection is the wrong question!

It is extremely unlikely that any now-known projection was used. So maybe **none** is correct.

None in the sense that no now-known projection was used.

But we know that all maps require a projection

Thus a projection constructed from empirical data is much more plausible, as described by Lanman and by Tobler.

It is reasonable to ask which modern projection comes closest to fitting the old chart.

But that is not a terribly interesting question.

It is, however, of interest to know how good, quantitatively, the charts are.

Especially in contrast to the contemporary ecclesiastical maps of the time.

Modern computing techniques should allow some answers.

An empirical examination based on

Coordinates From Scott Loomer

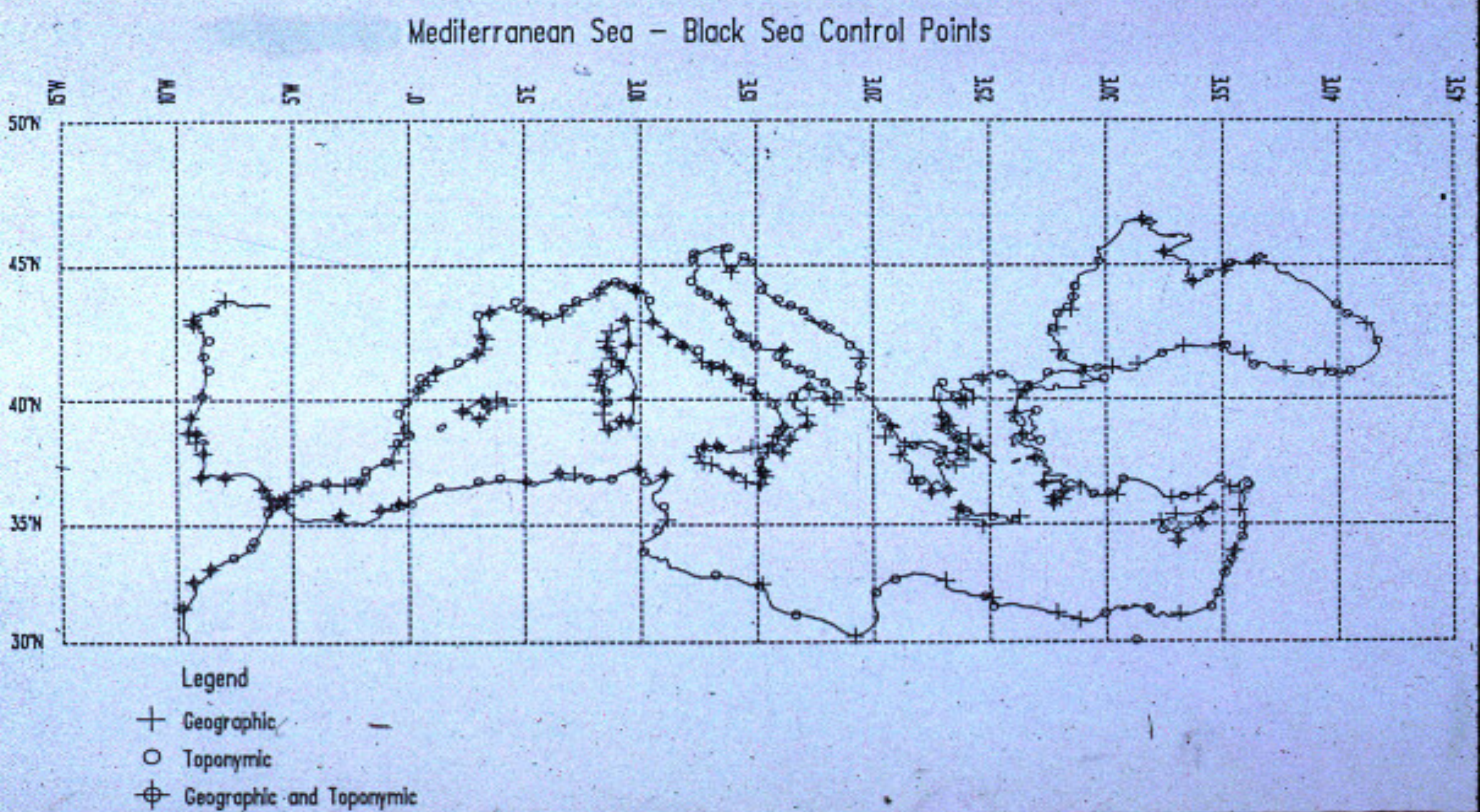
Mediterranean Sea - Black Sea Control Points

Num	Typ	Bas	Lat	Lon	Modern Name / Chart Name(s)[1]
Atlantic Coast, Northwest Spain to Gibraltar, 20 points					
1.005	G		43.77	-7.90	Cabo Ortegal
1.010	T		43.37	-8.40	La Coruna / Corogna, Collogna
1.020	T		43.10	-9.17	Mugia / Mongia
1.025	G		43.07	-9.32	Cabo Tourinan
1.030	B		42.87	-9.27	Cabo Finisterre / Finisterra
1.040	T		42.28	-8.60	Redondela / Radondella, Reondella
1.050	T		41.68	-8.83	Viana do Castello / Uiena, Viena
1.060	T		41.15	-8.62	Porto / Porto Gallo
1.062	B		40.18	-8.90	Cabo Mondego /. Mondego
1.065	B		39.35	-9.40	Cabo Carvoeiro / C. Carbon
1.068	B		38.77	-9.50	Cabo da Roca / Roca
1.070	B		38.73	-9.13	Lisboa / Lisbona
1.073	G		38.40	-9.22	Cabo Espichel
1.080	B		37.97	-8.88	Cabo de Sines / Sines, Signes
1.090	B		37.02	-8.98	C. de Sao Vincente / S. Uicenzo
1.100	T		37.02	-7.93	Faro / Faraum, Faran
1.103	G		36.97	-7.92	Cabo de Sta. Maria
1.105	B		36.53	-6.30	Cadiz / Cadis, Cades
1.107	B		36.18	-6.03	Cabo Trafalgar/ Trafagar, Trafalcar
1.110	B		36.02	-5.60	Punta Marroqui / Tarifa
Northwestern Mediterranean, Gibraltar to France, 31 points					
2.010	B	1	36.15	-5.35	Gibraltar / Gibeltar, Zubeltar
2.020	T	1	36.52	-4.88	Marbella / Marbela

[1]The chart names listed do not cover all variants but are representative of the variation in the spelling of the placename.

Mediterranean Nodes

From Loomer (1987)



Loomer compensated for geometric distortion as it might occur on an old portolan chart.

He did this by comparing the circular compass rose outline on the old chart with a true circle.

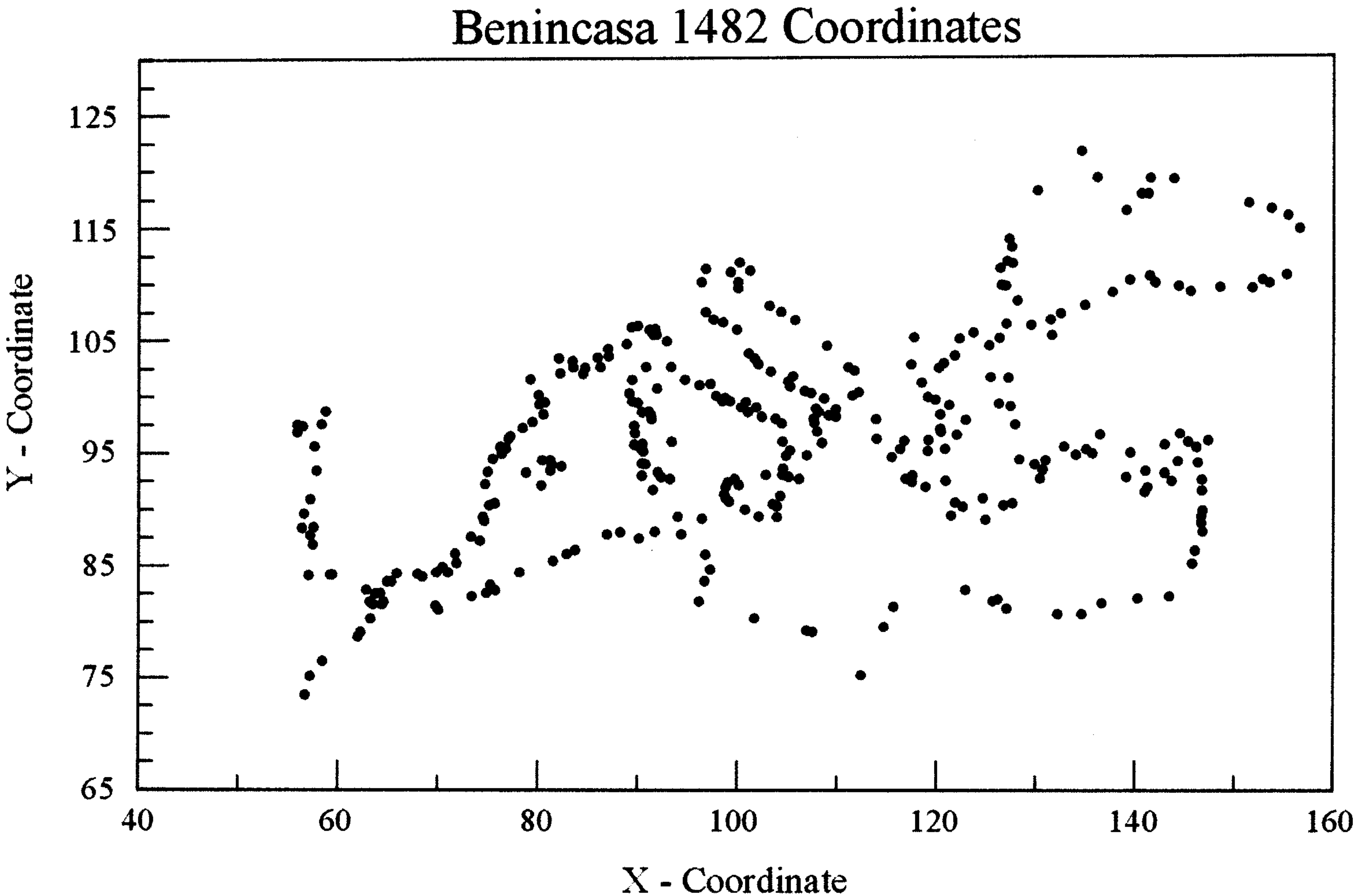
He then recorded the locational coordinates of the places after adjusting the circle.

Benincasa 1482
332 Observations
Longitude, latitude, X, Y, all from Loomer

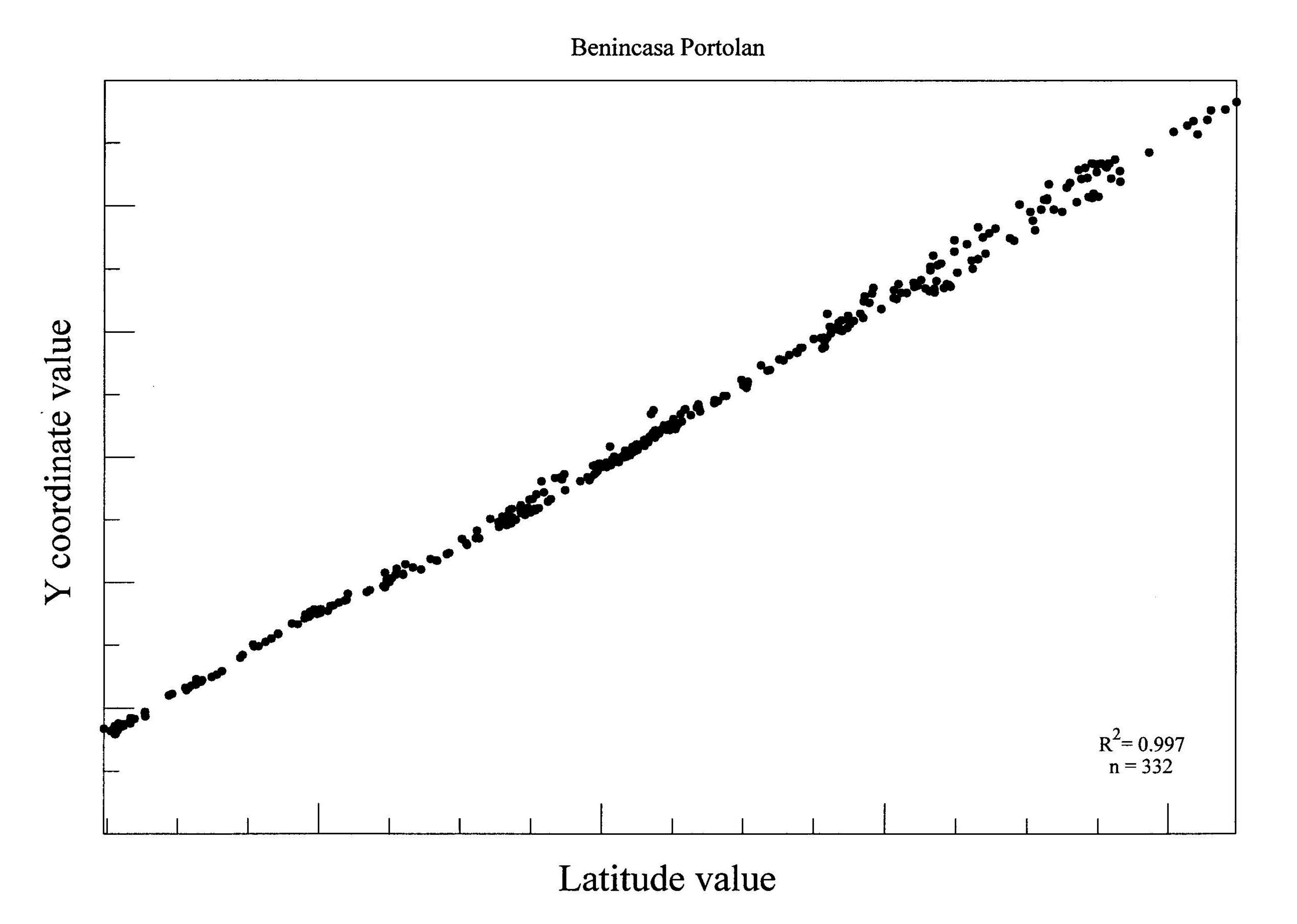
-6.14	43.77	58.66	98.69	1
-6.53	43.37	58.23	97.58	2
-7.13	43.10	56.42	97.37	3
-7.24	43.07	55.85	97.47	4
-7.20	42.87	55.85	96.82	5
-6.68	42.25	57.54	95.56	6
-6.70	41.15	57.80	93.43	7

to 332

Data locations

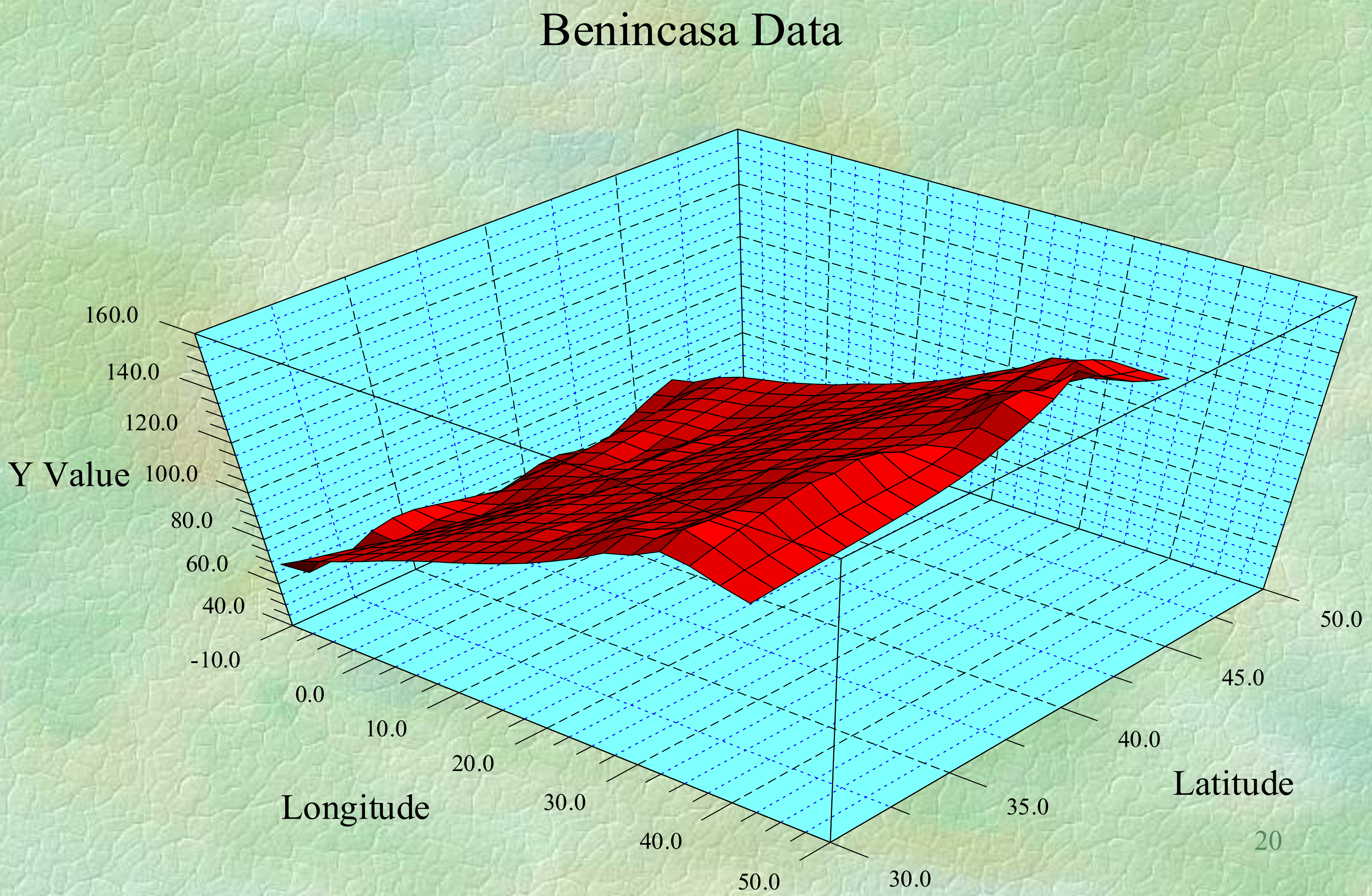


The fit to the latitudes

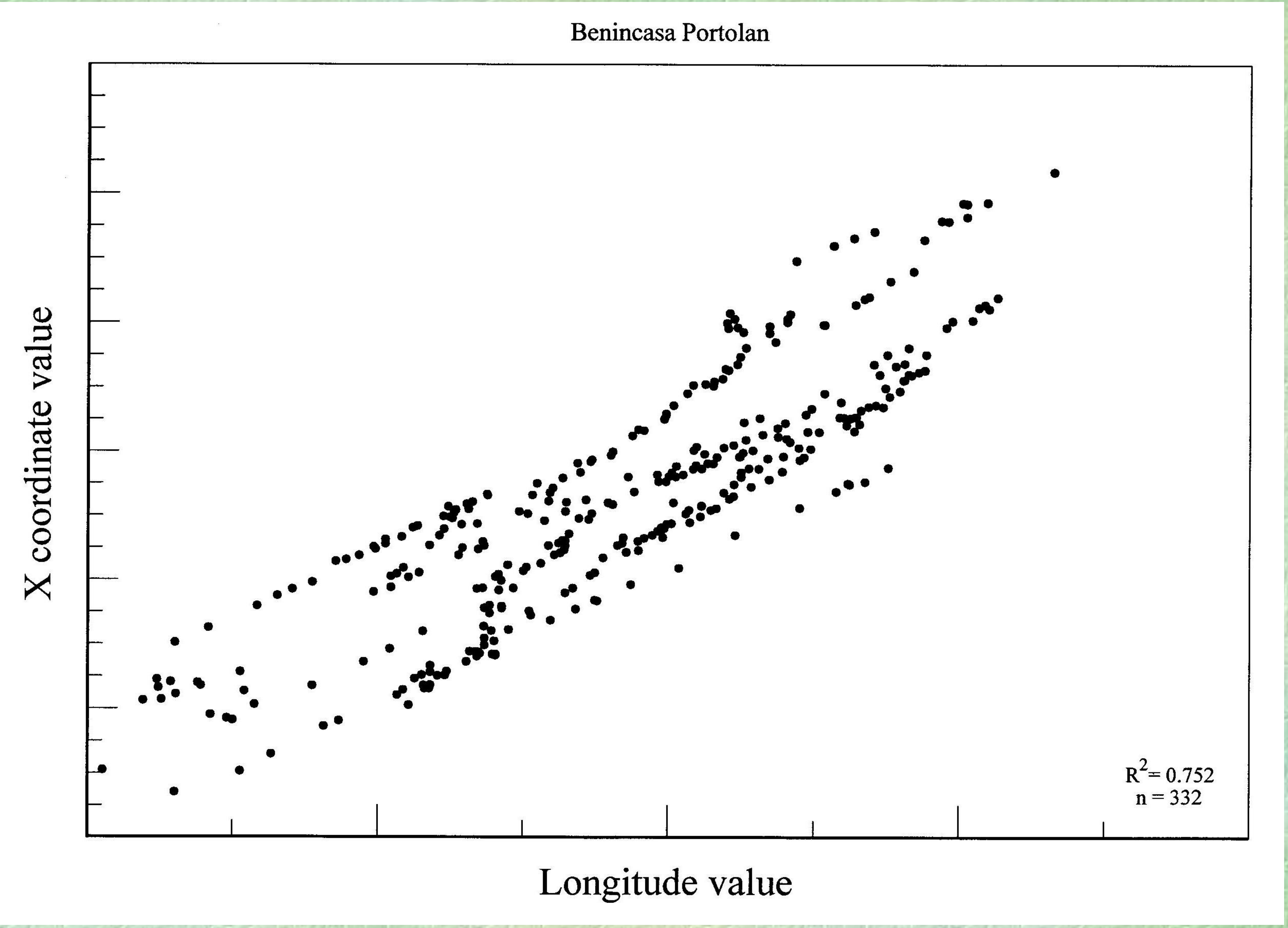


The Y-coordinate values

in relation to latitude and longitude



The fit to the longitudes



Conclusions from the previous slide!

The locations at the lower right are all along the Atlantic Coast. This reinforces earlier suggestions that a different measure of distance was used there.

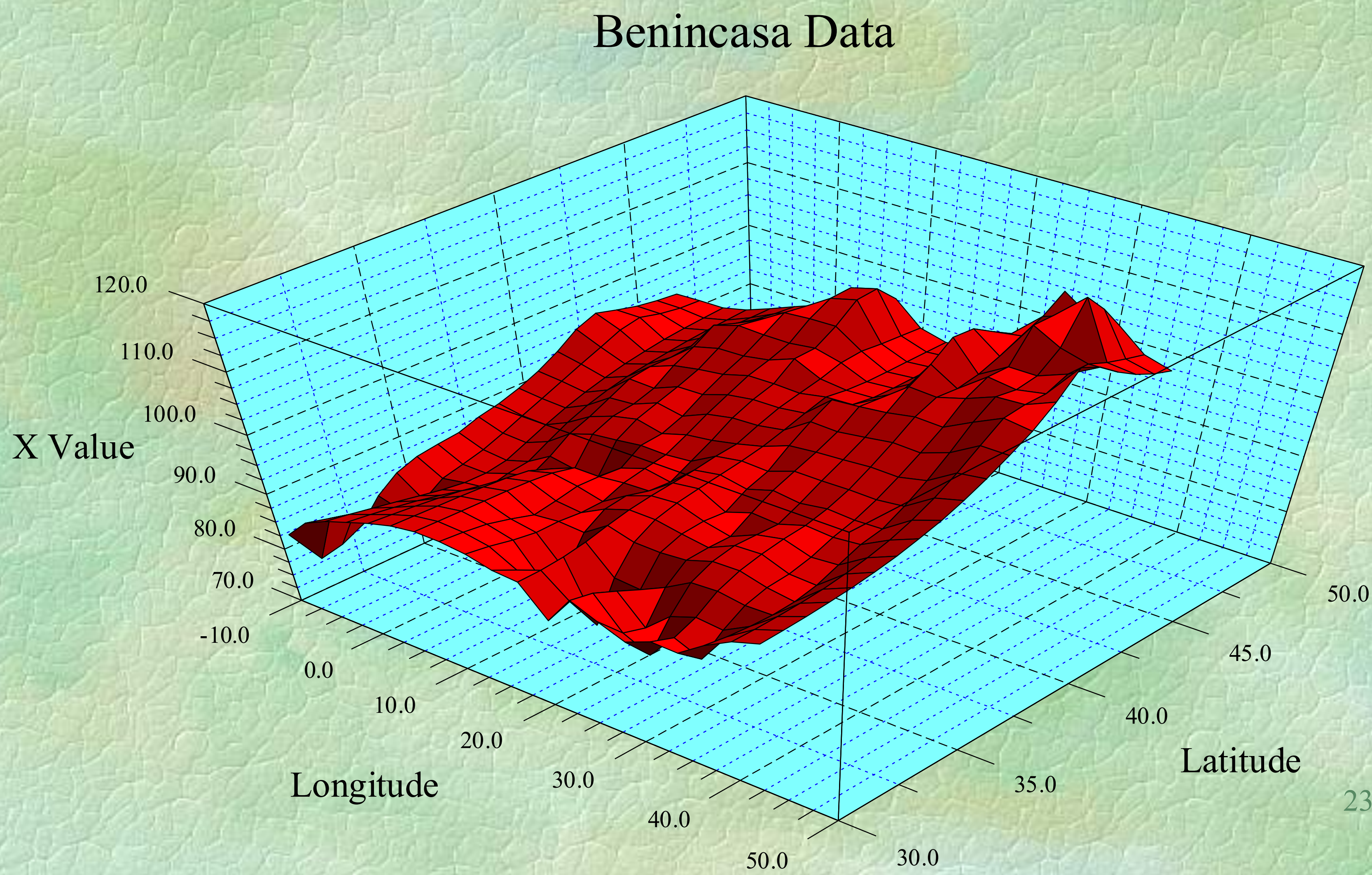
The locations at the upper left are not as clear but tend to be along the west coast of Greece.

The locations in the middle group are scattered throughout the chart.

Taken together these results tend to confirm Wagner's conclusion that the charts were constructed by piecing together several older charts.

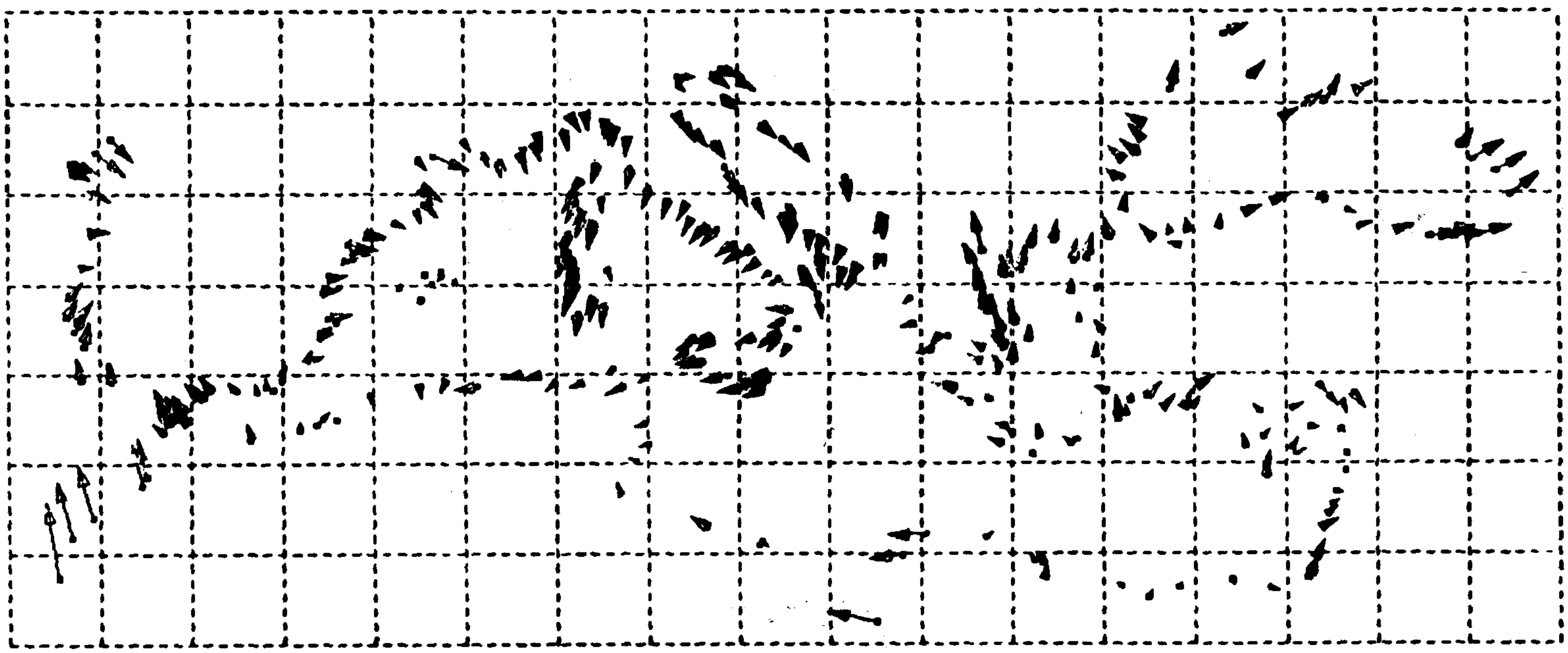
The overall correlation (R^2) is 0.752

The X-coordinate values
in relation to latitude and longitude



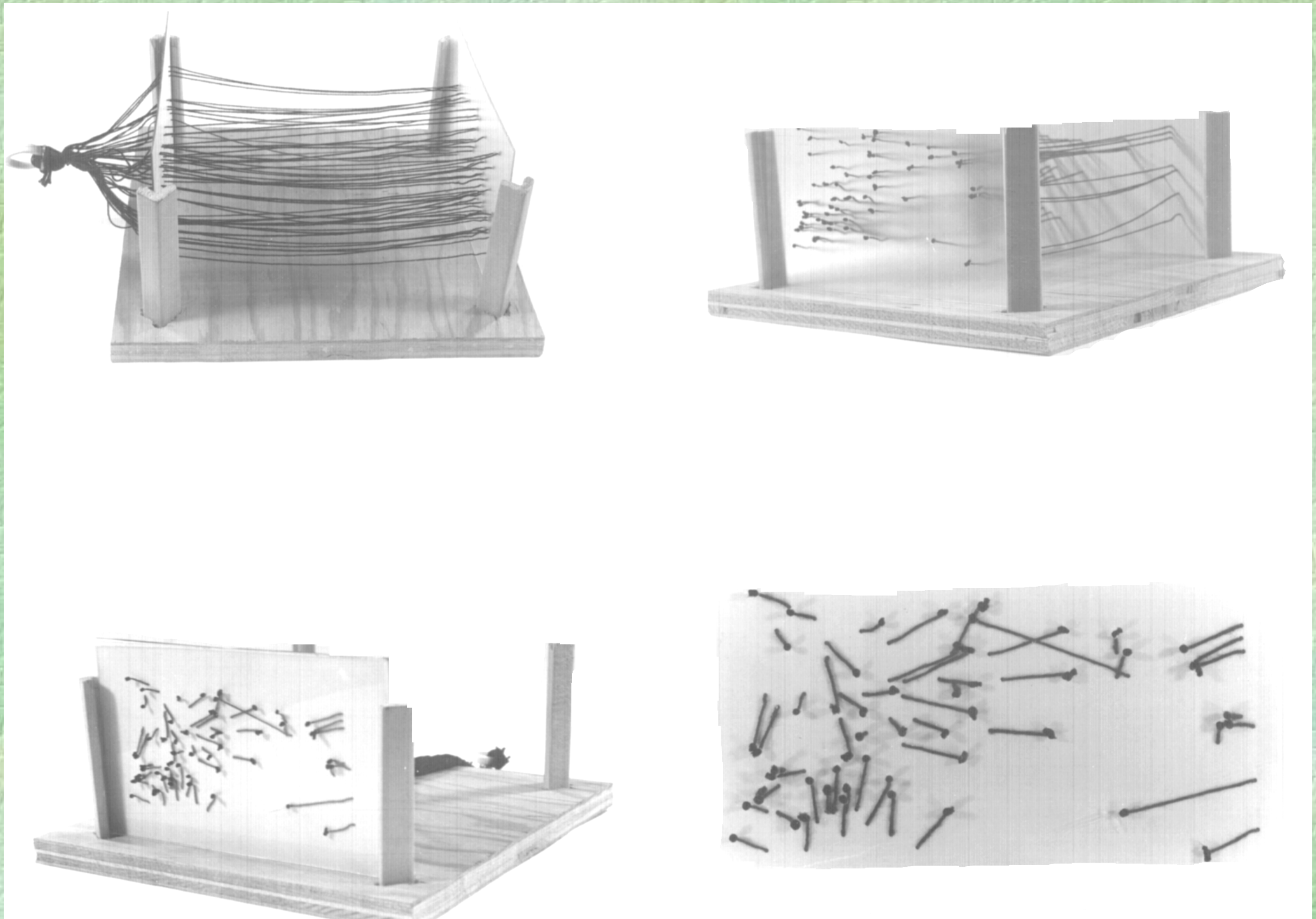
Mediterranean Displacements

After Loomer



To illustrate the displacement concept for students I have built

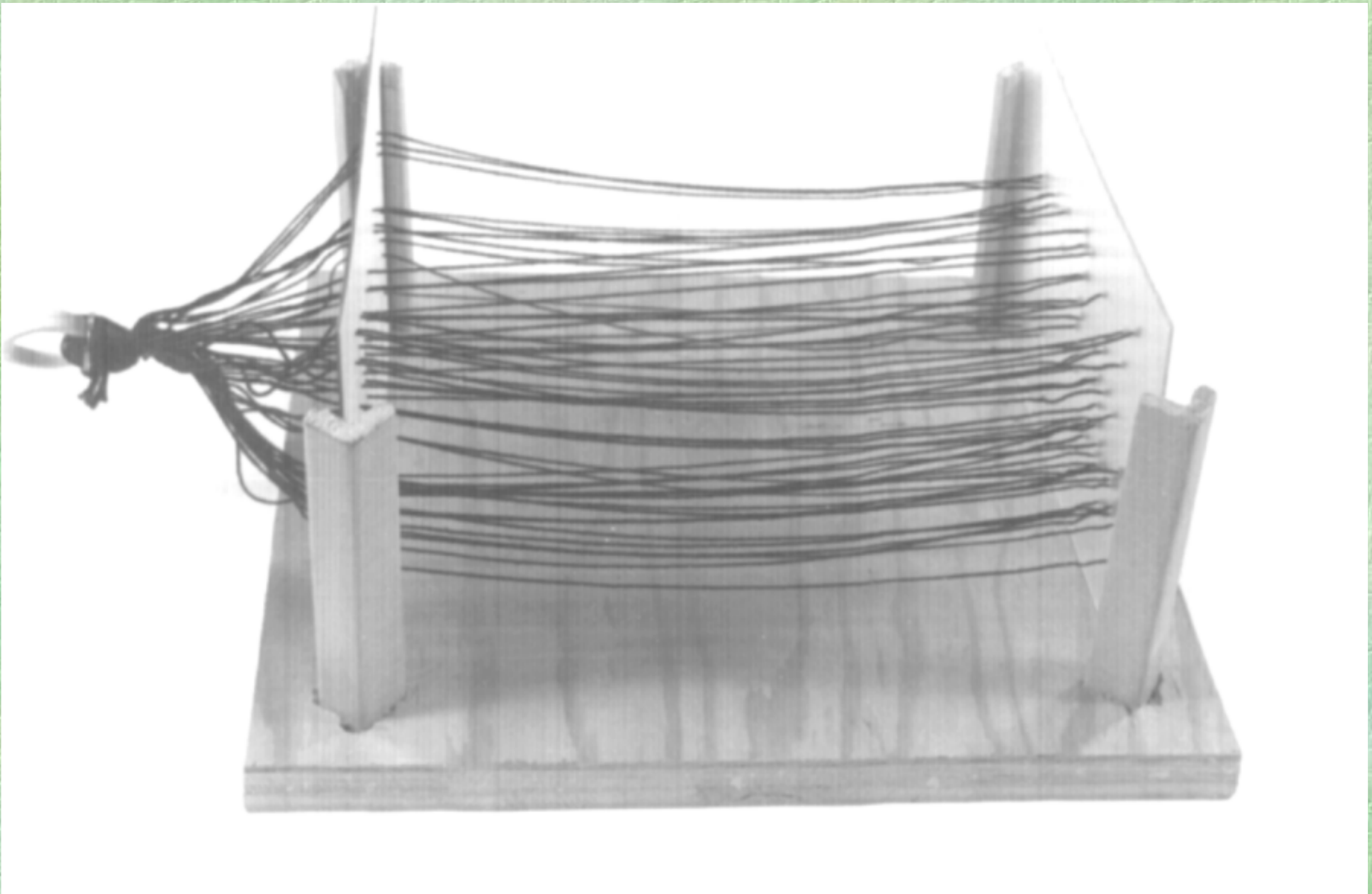
A Map Machine



The Map Machine

Used to illustrate the procedure for students

Showing the one to one correspondence between the images

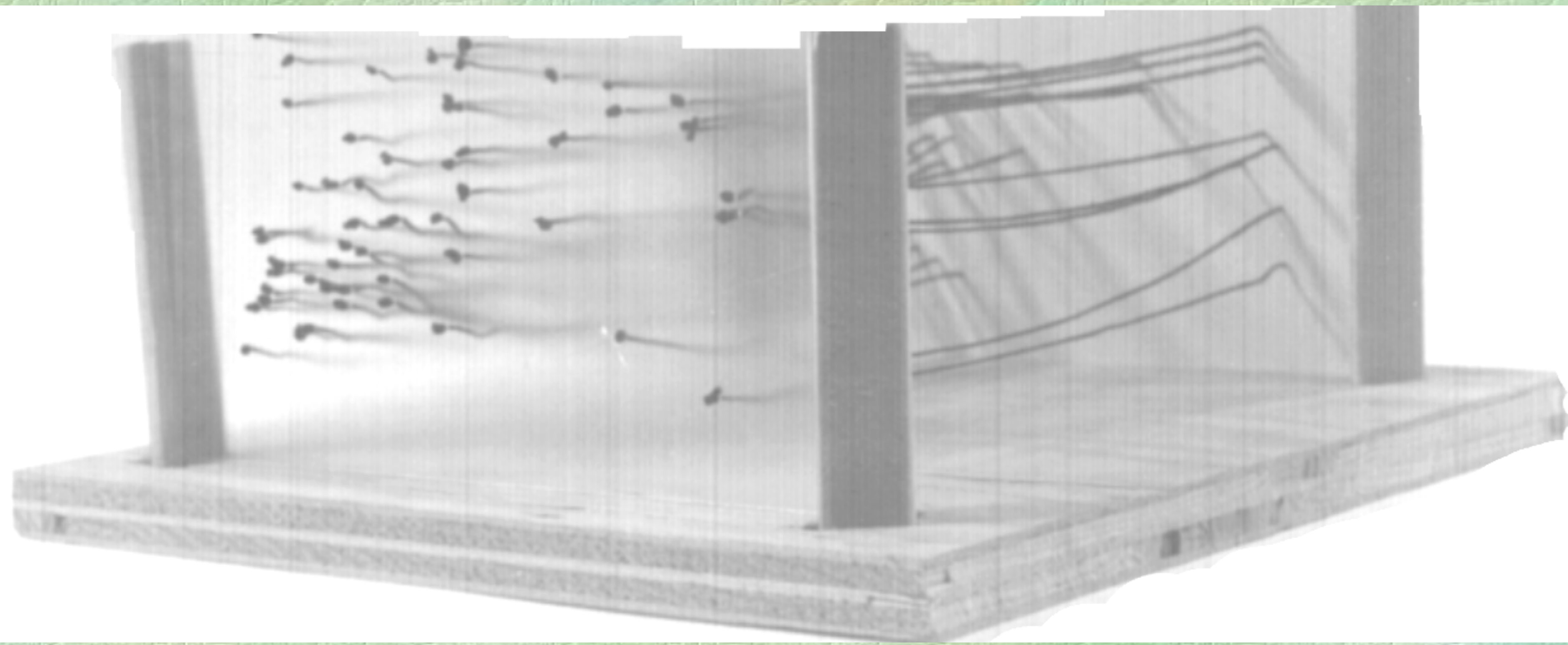


The Map Machine

Detail View

The front panel is transparent, back panel is white, strings are black

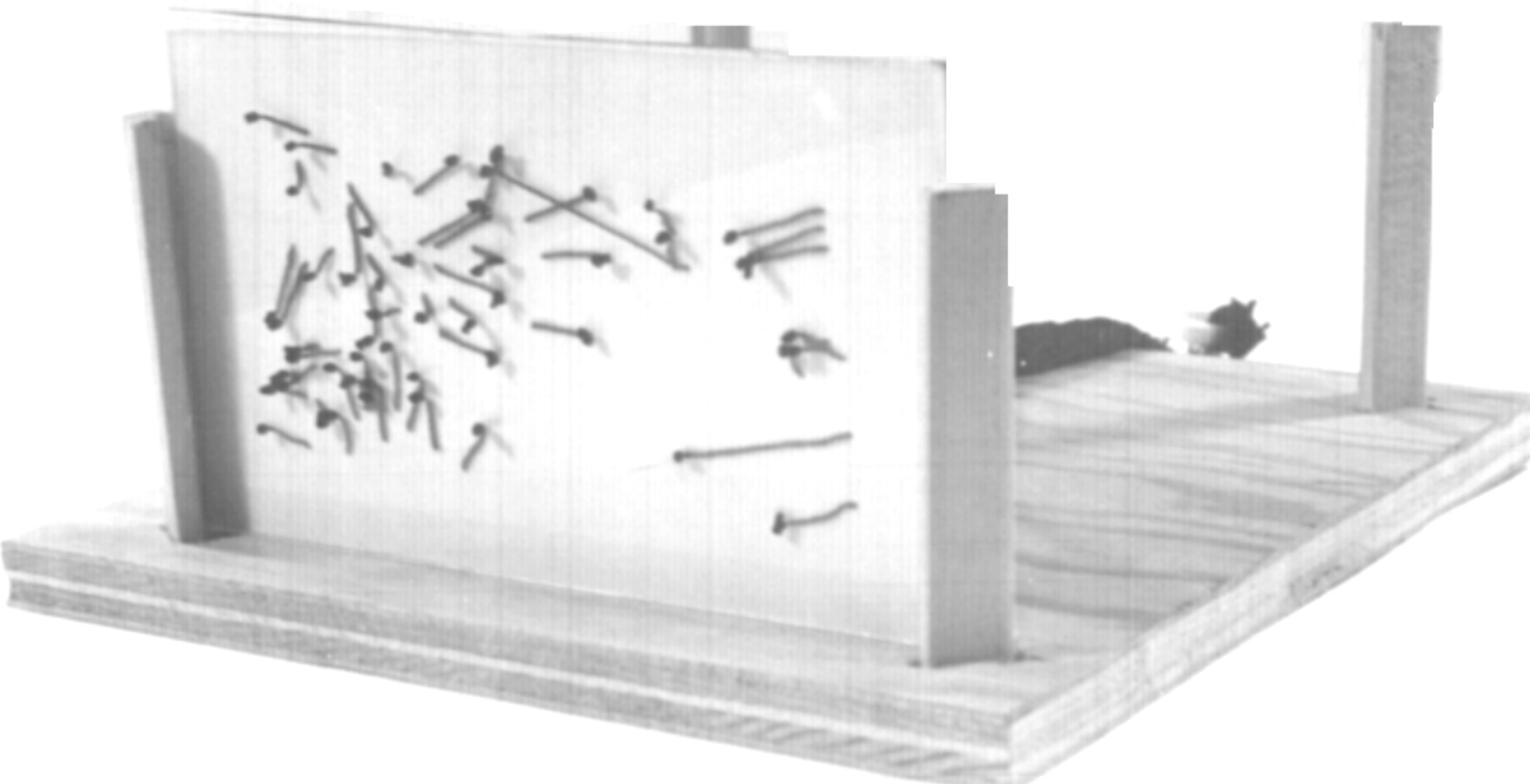
The old locations are positioned on the front panel, modern values on the back



The Map Machine

Showing the displacements

Releasing the back panel and pulling the strings together



The Bidimensional Regression Computer Program,

obtains the same effect as the map machine by estimating the difference between and original and an image.

The original can be a modern map and the image an old map.

The difference between locations on the two is used to compute displacements.

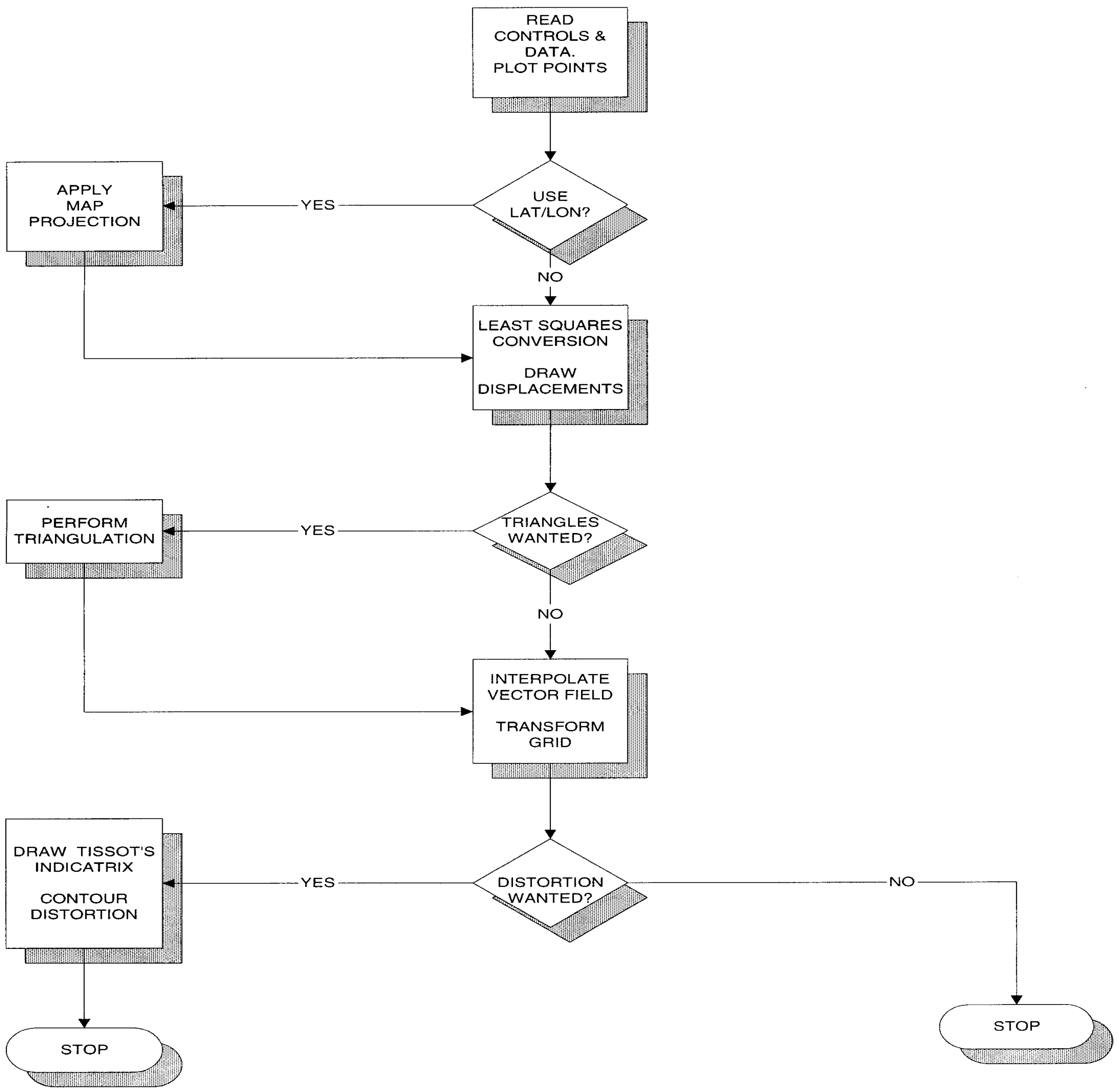
An interpolation is then performed to stretch one to fit the other.

This stretch is then examined mathematically,

and the distortion calculated.

A free version of the program is now available on the internet.

BIDIMENSIONAL REGRESSION PROGRAM

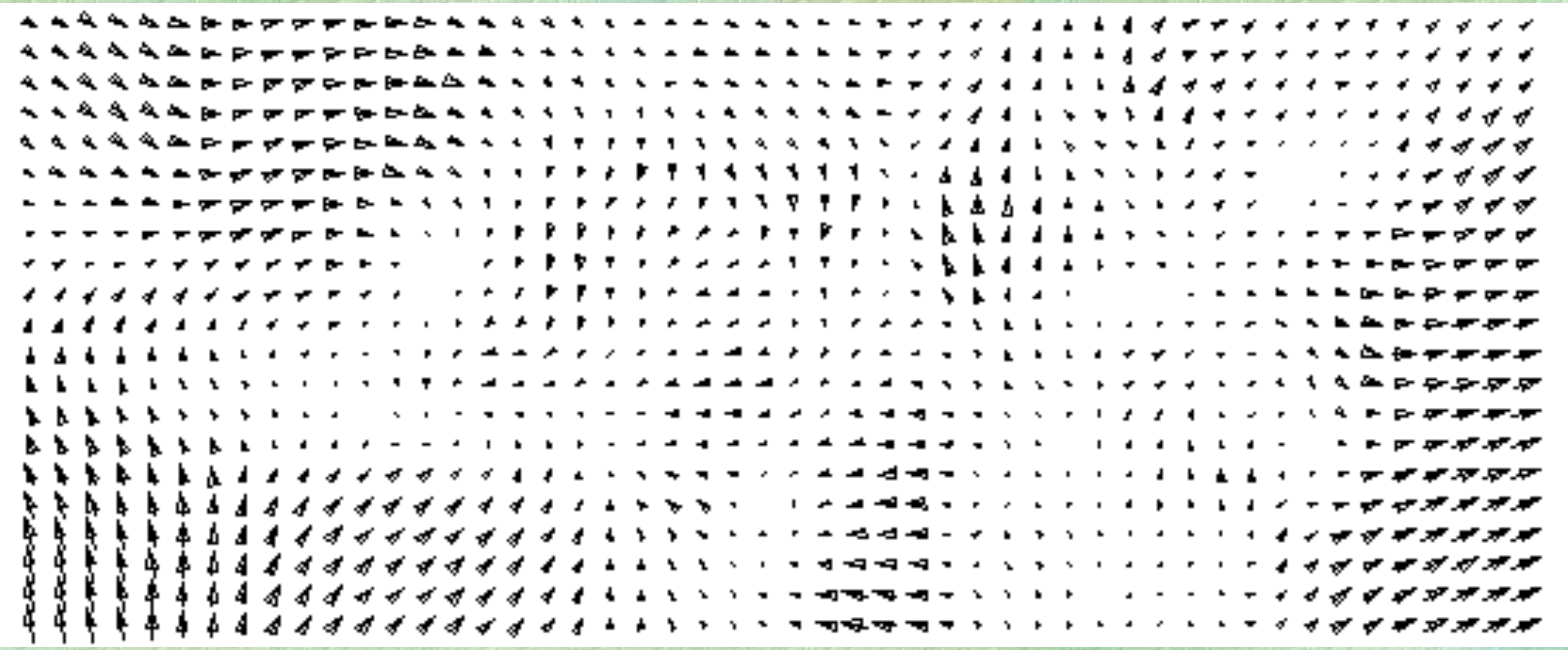


Waldo Tobler

Interpolated Vector Field

Based on Mediterranean displacements from Loomer’s thesis

Computed and drawn at half scale using the Bidimensional Regression computer program



What can be done with this vector field ?

Here are three possible things:

1) Use it to push the coordinate grid aside.

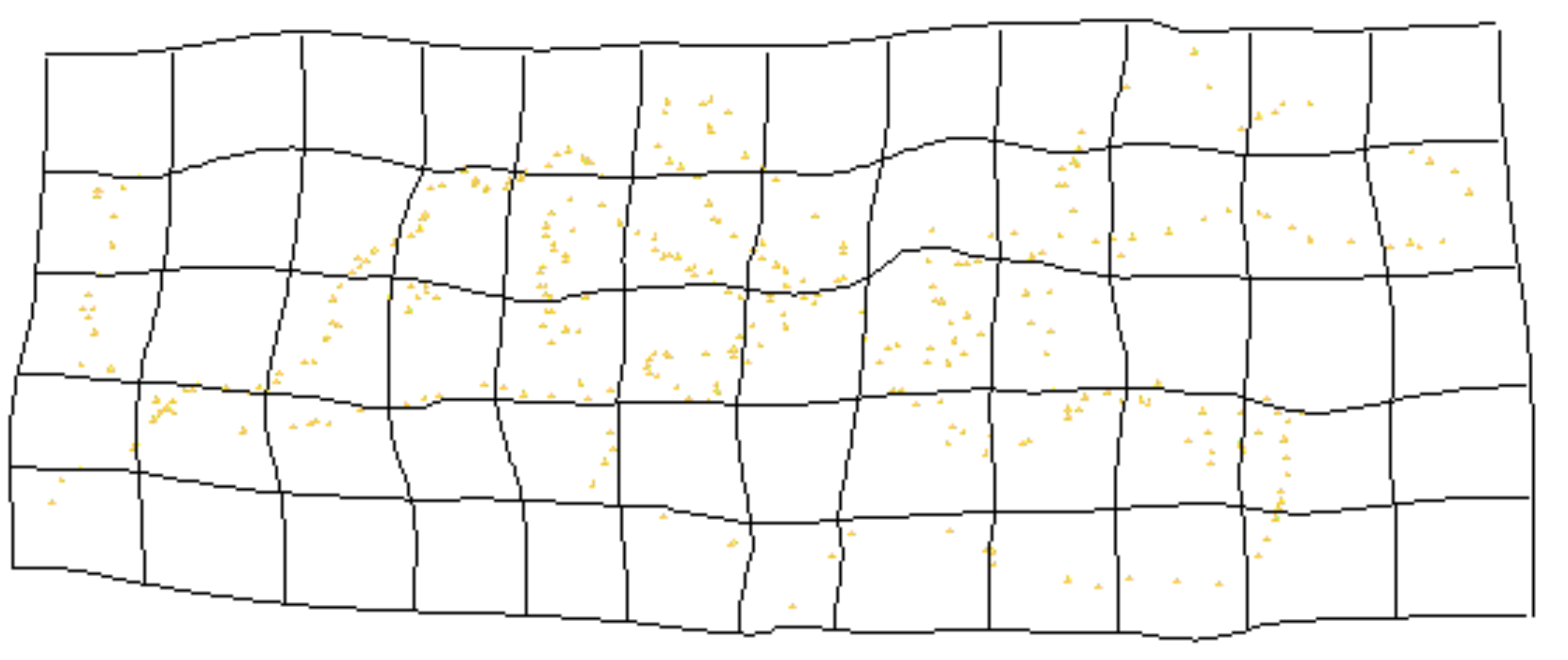
2) Assume that it is the result of a forcing function and work backwards to calculate the implied potential field.

3) Show the distortion tensor field to visualize the Tissot ellipses.

Warped Grid of Portolan Chart

As ‘pushed’ by the interpolated vector field

Computed and drawn using the Bidimensional Regression computer program



Coastlines and other detail may be drawn using the warped grid.

Observe that either the old map, or the modern one, can be considered the independent variable in this bidimensional regression.

Relating two sets of coordinates (the old and the new) requires a bidimensional correlation, instead of a regular unidimensional correlation.

The bidimensional correlation can be linear or curvilinear.

W. Tobler, 1994, "Bidimensional Regression", *Geographical Analysis*

A simple measure of total distortion at each point is the sum of squares of the partial derivatives of the transformation.

This is shown on the next slide.

It is easier to understand than more complicated measures of distortion.

But there are several alternatives.

Contours of the total distortion on the 1482 Portolan

Sum of squares of the partial derivatives computed from the displacement vectors.

Computed and drawn by the Bidimensional Regression computer program

Tissot's Indicatrix also Measures distortion

Calculation of this index allows one to estimate where the map is conformal or equal area, or nearly so.

It is based on the four partial derivatives of the transformation,

$\partial u/\partial x$, $\partial v/\partial x$, $\partial u/\partial y$, $\partial v/\partial y$.

Infinitesimal circles on the original appear as ellipses in the image. Conversely, circles in the image are ellipses in the original.

The shape of the ellipses illustrates departures from conformality.

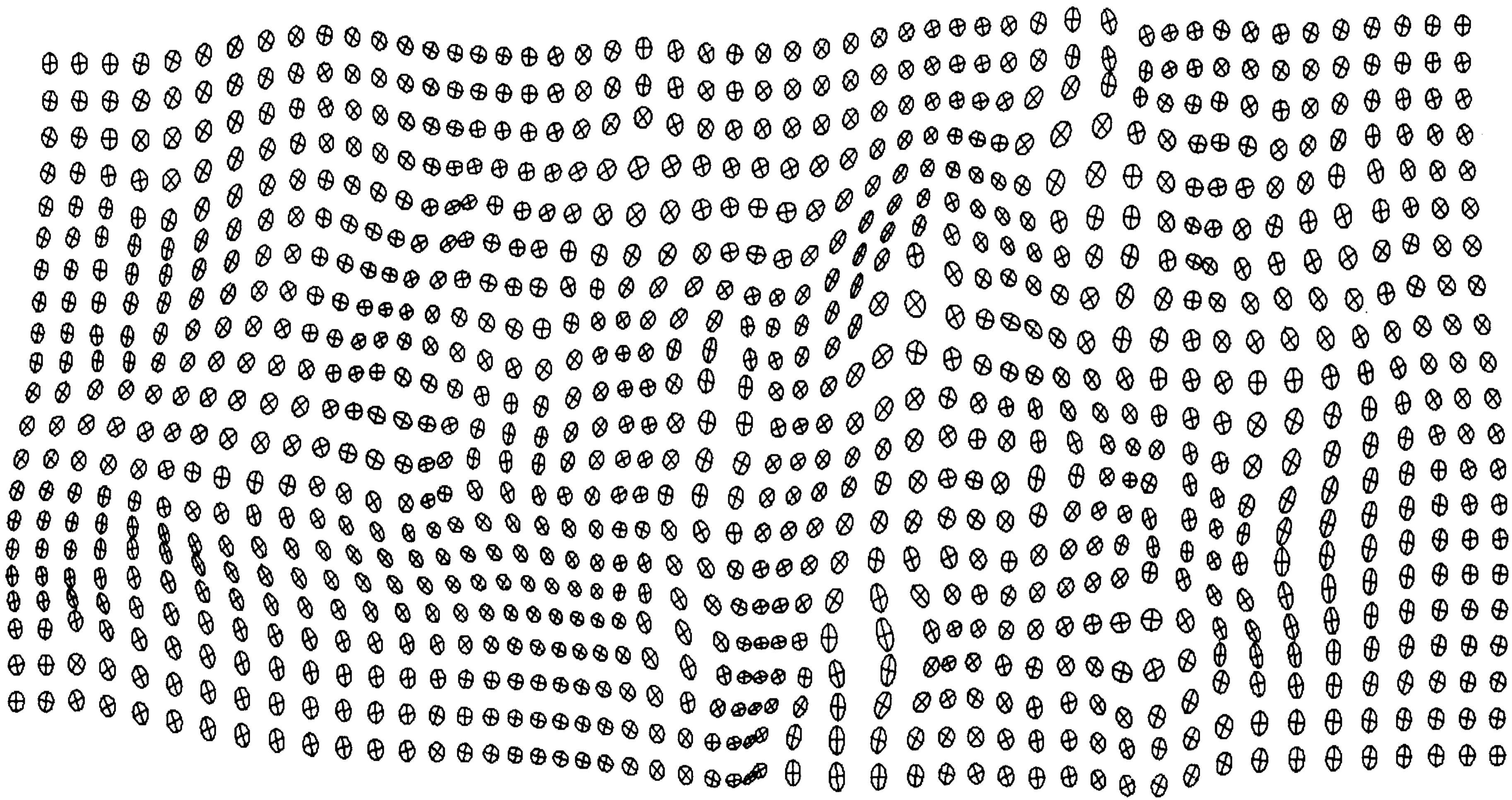
The area of the ellipses illustrates areal exaggeration.

The eccentricity of the ellipses shows the linear stretch.

As such the index is a tensor function of location. It varies from place to place, and reflects the fact that **map scale is always different in every direction** at a location, unless the map is conformal.

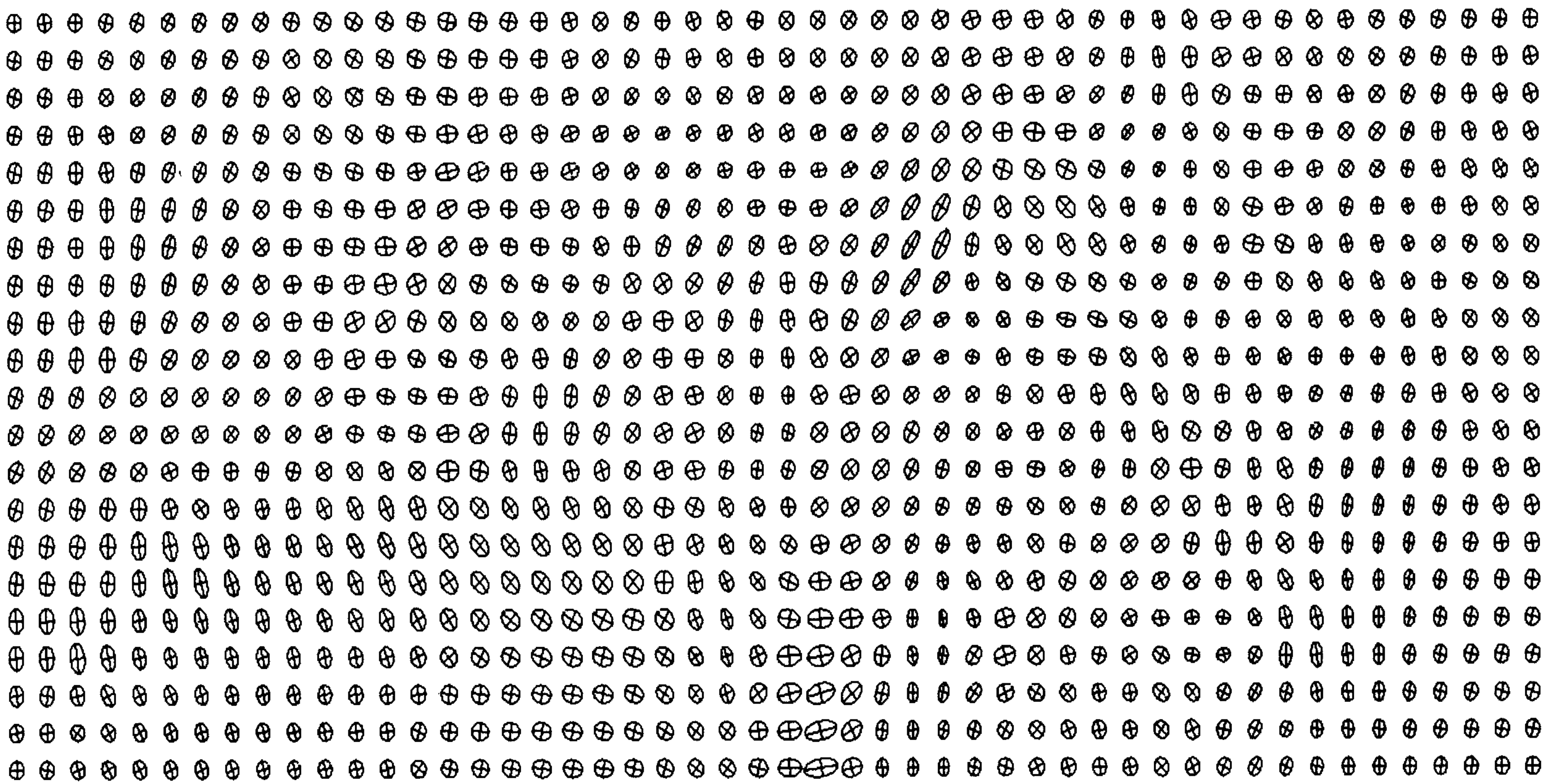
Tissot’s indicatrix in the image

Calculated and drawn by the Bidimensional Regression computer program



Tissot's indicatrix in the original

Calculated and drawn by the Bidimensional Regression computer program



Conclusions

Tissot's measures indicate that this portolan chart is neither conformal nor equal area.

Suggestions that it is based on a now-known map projection are erroneous.

It is more likely that it was based on empirical measurements (loxodromic distances and directions) in the Mediterranean,

and was thus constructed to fit an unconscious hypothesis that the earth is flat, resulting in an empirical map projection,

and was put together from several separate sectional maps.

Some References

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J. Lanman, 1987, On the Origin of Portolan Charts, The Newberry Library, Chicago, 56pp.

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M. Tissot, 1881, Memoire sur la representation des surfaces et les projections des cartes geographiques, Hermann, Paris, 260 pp.

W. Tobler, 1966, "Medieval Distortions: The Projections of Ancient Maps", Annals, Association of American Geographers, 56(2):351-360.

W. Tobler , 1977, "Numerical Approaches to Map Projections", pp 51-64 of Kretschmer, ed., Studies in Theoretical Cartography, Vienna, Deuticke.

W. Tobler, 1994, "Bidimensiomnal Regression", Geographical Analysis, 26:186-212; Bidimensional Regression Computer Program 1974.

H. Wagner, 1895, "Das Raetzel der Kompasskarten im Lichte der Gesamt- entwicklung der Seekarten", Verhandlungen, XI Deutsches Geographentages, Bremen pp 65-87.

Bidimensional Regression online: www.spatial-modelling.info/Darcy-2-module-de-comparison

Thank you for your attention

Questions?

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