UNIVERSIDADE DO ALGARVE
FACULDADE DE CIÊNCIAS E TECNOLOGIA

Georeferencer
Plugin

TUTORIAL

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SCAN ME

com QGIS 3.22.4 LTR - Białowieża

v.02.01

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OBJECTIVOS

Para além da **informação georreferenciada em suporte digital**, com estrutura vectorial e que constitui uma parcela fundamental de qualquer **projecto GIS**, existem outras fontes de informação em suporte físico convencional, que podem revestir-se de grande interesse para o enriquecimento e diversificação da informação que integra o projecto QGIS.

Cartas e **mapas** em papel, e **fotografias aéreas** ou **ortofotomapas** em papel fotográfico, são exemplos desses tipos de informação.

É simples proceder à *scannerização* desses materiais, e a partir dos ficheiros resultantes integrá-los então num projecto QGIS...

O objectivo do presente tutorial é apresentar um conjunto de procedimentos com vista a **converter** essa **informação**, do suporte convencional **para *layers***, em formato *raster*, devidamente **georreferenciadas**.

Procedimentos

A conversão de cartografia em papel, e de **fotografias aéreas** e **ortofotomapas** em papel fotográfico, começa com um procedimento de *scannerização*, o qual não é detalhado neste tutorial.

Através do mesmo, o suporte convencional é convertido em suporte digital não georreferenciado, constituindo-se apenas como um ficheiro em formato ***.tif** ou ***.tiff** (*tagged image file*), ***.png** (*portable network graphics*), ou ***.jpg** ou ***.jpeg** (*joint photographic expert group*).

Em seguida, o ficheiro é importado para o **Plugin QGIS Georeferencer...** Aí é feita a conversão do ficheiro numa ***layer raster***, devidamente georreferenciada. Essa ***layer*** pode então integrar o projecto GIS e, até, ser depois vectorizada...

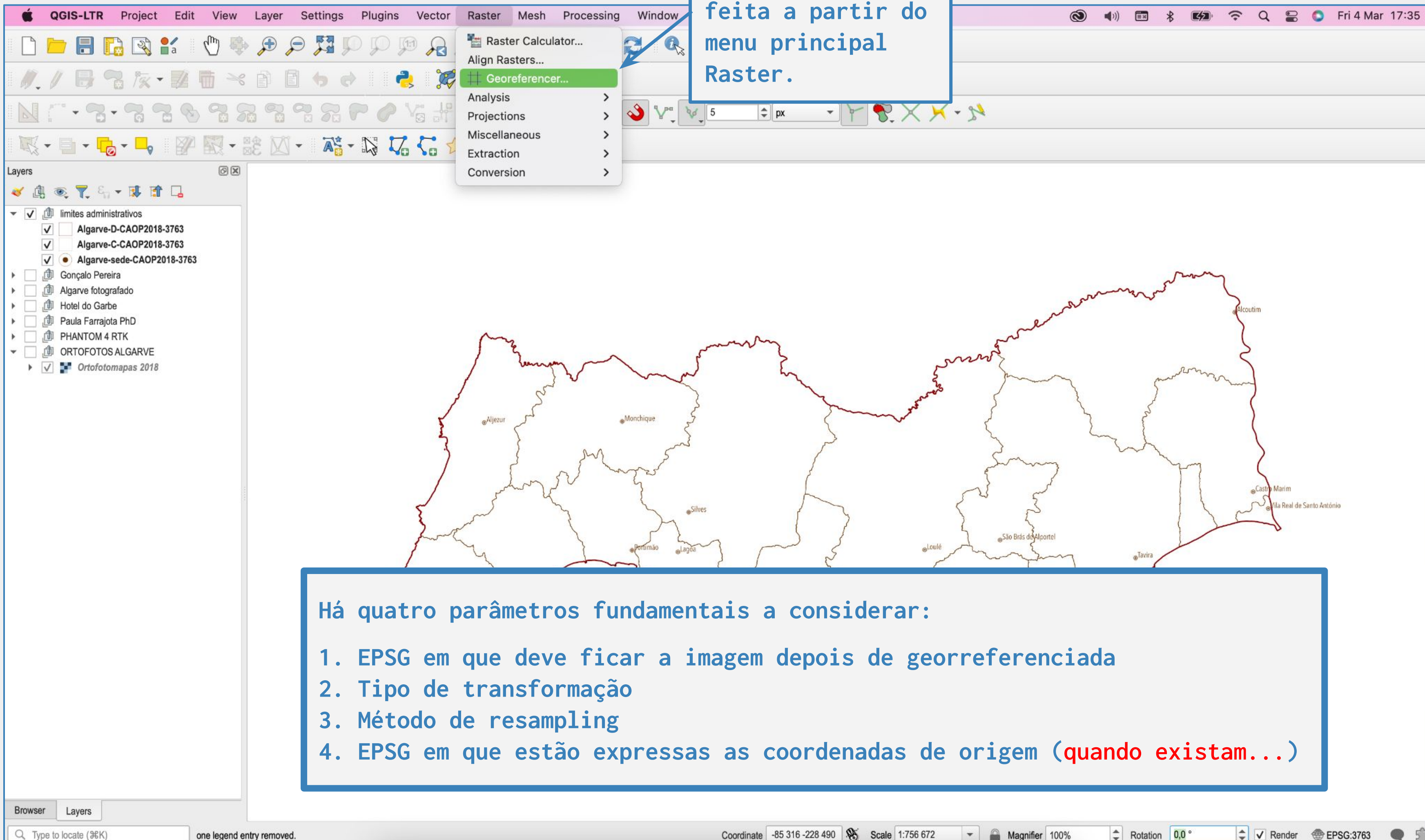
Georeferencer

Plugin

QGIS User Guide

Introdução…

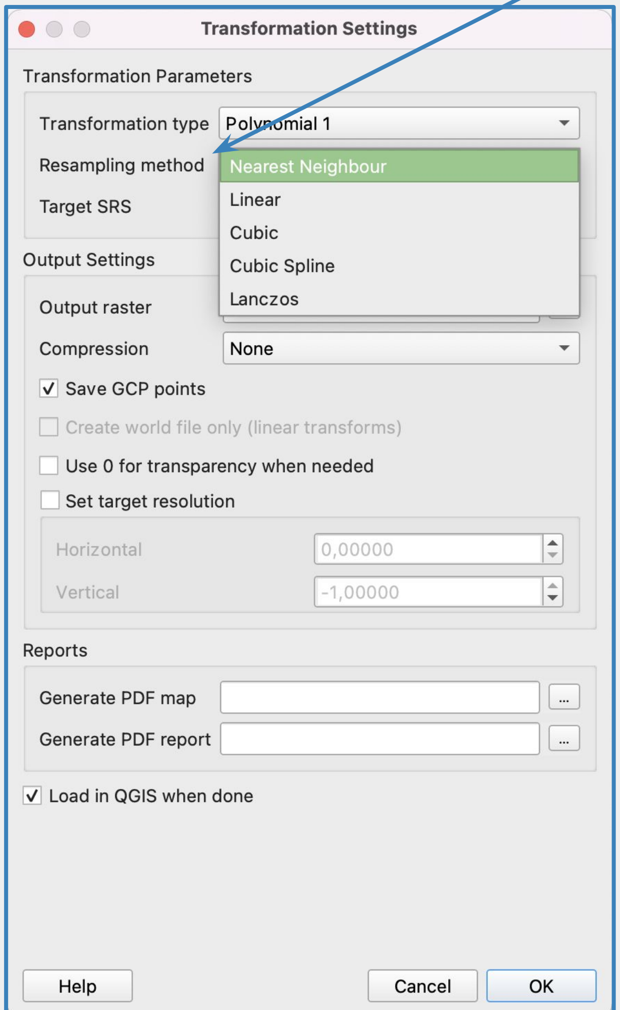
1. A activação do Georeferencer é feita a partir do menu principal Raster.



Há quatro parâmetros fundamentais a considerar:

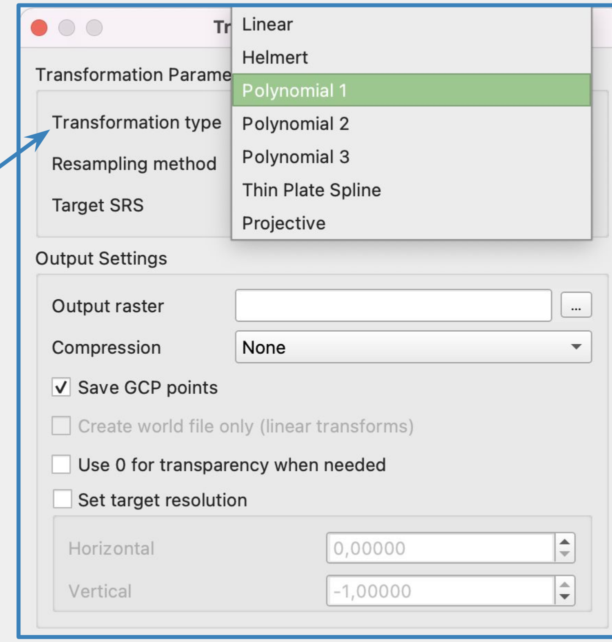
1. EPSG em que deve ficar a imagem depois de georreferenciada
2. Tipo de transformação
3. Método de resampling
4. EPSG em que estão expressas as coordenadas de origem (quando existam…)

Introdução...

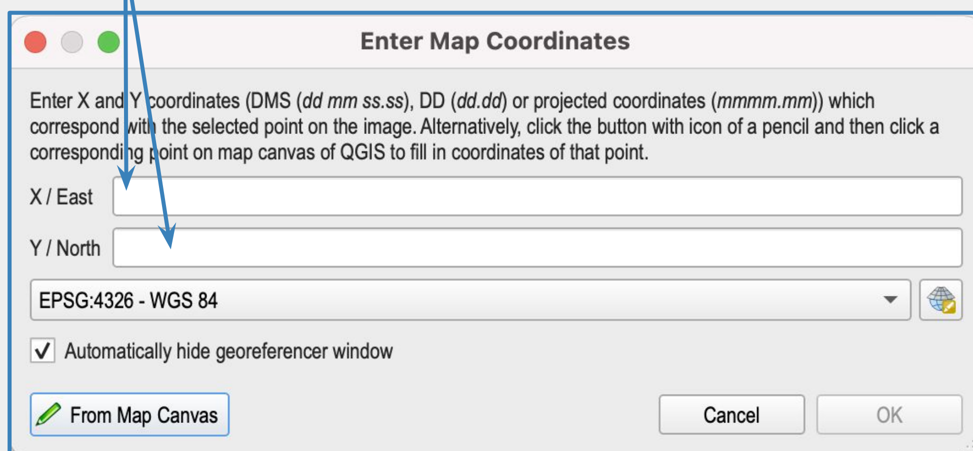


2. Configuração do Método de resampling.

3. Configuração do Tipo de transformação.



4.1. Introdução numérica das Coordenadas e do EPSG em que estão expressas.



Transformation type

Currently, the following **Transformation types** are available:

- The **Linear** algorithm is used to create a world file and is different from the other algorithms, as it does not actually transform the raster pixels. It allows positioning (translating) the image and uniform scaling, but no rotation or other transformations. It is the most suitable if your image is a good quality raster map, in a known CRS, but is just missing georeferencing information. At least 2 GCPs are needed.
- The **Helmert** transformation also allows rotation. It is particularly useful if your raster is a good quality local map or orthorectified aerial image, but not aligned with the grid bearing in your CRS. At least 2 GCPs are needed.
- The **Polynomial 1** algorithm allows a more general affine transformation, in particular also a uniform shear. Straight lines remain straight (i.e., collinear points stay collinear) and parallel lines remain parallel. This is particularly useful for georeferencing data cartograms, which may have been plotted (or data collected) with different ground pixel sizes in different directions. At least 3 GCP's are required.
- The **Polynomial** algorithms 2-3 use more general 2nd or 3rd degree polynomials instead of just affine transformation. This allows them to account for curvature or other systematic warping of the image, for instance photographed maps with curving edges. At least 6 (respectively 10) GCP's are required. Angles and local scale are not preserved or treated uniformly across the image. In particular, straight lines may become curved, and there may be significant distortion introduced at the edges or far from any GCPs arising from extrapolating the data-fitted polynomials too far.
- The **Projective** algorithm generalizes Polynomial 1 in a different way, allowing transformations representing a central projection between 2 non-parallel planes, the image and the map canvas. Straight lines stay straight, but parallelism is not preserved and scale across the image varies consistently with the change in perspective. This transformation type is most useful for georeferencing angled photographs (rather than flat scans) of good quality maps, or oblique aerial images. A minimum of 4 GCPs is required.
- Finally, the **Thin Plate Spline** (TPS) algorithm "rubber sheets" the raster using multiple local polynomials to match the GCPs specified, with overall surface curvature minimized. Areas away from GCPs will be moved around in the output to accommodate the GCP matching, but will otherwise be minimally locally deformed. TPS is most useful for georeferencing damaged, deformed, or otherwise slightly inaccurate maps, or poorly orthorectified aerials. It is also useful for approximately georeferencing and implicitly reprojecting maps with unknown projection type or parameters, but where a regular grid or dense set of ad-hoc GCPs can be matched with a reference map layer. It technically requires a minimum of 10 GCPs, but usually more to be successful.

In all of the algorithms except TPS, if more than the minimum GCPs are specified, parameters will be fitted so that the overall residual error is minimized. This is helpful to minimize the impact of registration errors, i.e. slight imprecisions in pointer clicks or typed coordinates, or other small local image deformations. Absent other GCPs to compensate, such errors or deformations could translate into significant distortions, especially near the edges of the georeferenced image. However, if more than the minimum GCPs are specified, they will match only approximately in the output. In contrast, TPS will precisely match all specified GCPs, but may introduce significant deformations between nearby GCPs with registration errors.

Resampling method

The type of resampling you choose will likely depend on your input data and the ultimate objective of the exercise. If you don't want to change statistics of the raster (other than as implied by nonuniform geometric scaling if using other than the Linear, Helmert, or Polynomial 1 transformations), you might want to choose 'Nearest neighbour'. In contrast, 'cubic resampling', for instance, will usually generate a visually smoother result.

It is possible to choose between five different resampling methods:

1. Nearest neighbour
2. Linear
3. Cubic
4. Cubic Spline
5. Lanczos

There are five choices for **Resampling method**. During the transformation, a new output raster will be generated. This setting will determine how the pixel values will be calculated in the output raster. Each is described here; for this example, choose **Linear**:

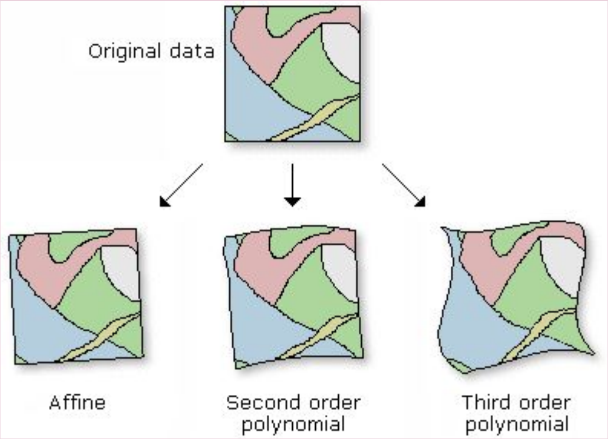
- **Nearest neighbour**: In this method, the value of an output pixel values will be determined by the value of the nearest cell in the input. This is the fastest method and it will not change pixel values during the transformation. It is recommended for categorical or integer data. If it is used with continuous data, it produces blocky output.
- **Linear**: This method uses the four nearest input cell values to determine the value of the output cell. The new cell value is a weighted average of the four input cell values. It produces smooth output because high and low input cell values may be eliminated in the output. It is recommended for continuous datasets. It should not be used on categorical data because the input categories may not be maintained in the output.
- **Cubic**: This is similar to **Linear**, but it uses the 16 nearest input cells to determine the output cell value. It is better at preserving edges, and the output is sharper than the **Linear** resampling. It is often used with aerial photography or satellite imagery and is also recommended for continuous data. This should not be used for categorical data for the same reasons that were given for the **Linear** resampling.
- **Cubic Spline**: This algorithm is based on a spline function and produces smooth output.
- **Lanczos**: This algorithm produces sharp output. It must be used with caution because it can result in output values that are both lower and higher than those in the input.

Transforming the raster

When you've created enough links (or CONTROL POINTS), you can transform - or warp - the raster dataset to permanently match the map coordinates of the target data. You have the choice of using a **polynomial**, **spline**, or **adjust transformation** to determine the correct map coordinate location for each cell in the raster.

The **POLYNOMIAL TRANSFORMATION** uses a polynomial built on control points and a least squares fitting (LSF) algorithm. It is **optimized for global accuracy but does not guarantee local accuracy**. The polynomial transformation yields two formulas: one for computing the output x-coordinate for an input (x,y) location and one for computing the y-coordinate for an input (x,y) location. The goal of the LSF algorithm is to derive a general formula that can be applied to all points, usually at the expense of slight movement of the to positions of the control points. The number of the non-correlated **control points** required for this method must be **3 for a first-order**, **6 for a second-order**, and **10 for a third-order**. The first-order polynomial transformation is commonly used to georeference an image.

Use a **first-order** or **affine** transformation to shift, scale, and rotate a raster dataset. This generally results in straight lines on the raster dataset mapped as straight lines in the warped raster dataset. Thus, squares and rectangles on the raster dataset are commonly changed into parallelograms of arbitrary scaling and angle orientation. With a minimum of three links, the mathematical equation used with a first-order transformation can exactly map each raster point to the target location. Any more than three links introduces errors, or residuals, that are distributed throughout all the links. Even though the mathematical transformation error may increase as you create more links, the overall accuracy of the transformation will increase as well.



The higher the transformation order, the more complex the **distortion** that can be corrected. However, transformations higher than third order are rarely needed. Higher-order transformations require more links and, thus, will involve progressively more processing time. In general, if your raster dataset needs to be stretched, scaled, and rotated, use a first-order transformation. If, however, the raster dataset must be bent or curved, use a second- or third-order transformation.

http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Georeferencing_a_raster_dataset

Transforming the raster (cont.)

The **spline transformation** is a 'true rubber sheeting' method and optimizes for local accuracy but not global accuracy. It is based on a spline function - a piecewise polynomial that maintains continuity and smoothness between adjacent polynomials. Spline transforms the source control points exactly to target control points; the pixels that are a distance from the control points are not guaranteed to be accurate. This transformation is useful when the control points are important and it is required that they be registered precisely. Adding more control points can increase overall accuracy of the spline transformation. Spline requires a minimum of ten control points.

The **adjust transformation** optimizes for both global LSF and local accuracy. It is built on an algorithm that combines a polynomial transformation and a triangulated irregular network (TIN) interpolation technique. The adjust transformation performs a polynomial transformation using two sets of control points and adjusts the control points locally to better match the target control points using a TIN interpolation technique. Adjust requires a minimum of three control points.

Interpreting the root mean square error

When the general formula is derived and applied to the control point, a measure of the error - **the residual error** - is returned.

The error is the difference between where the from point ended up as opposed to the actual location that was specified - the to point position. The total error is computed by taking the **root mean square** (RMS) **sum** of all the residuals to compute the RMS error. This value describes how consistent the transformation is between the different control points (links).

Although the RMS error is a good assessment of the transformation's accuracy, don't confuse a low RMS error with an accurate registration. For example, the transformation may still contain significant errors due to a poorly entered control point. The more control points of equal quality used, the more accurately the polynomial can convert the input data to output coordinates. Typically, the adjust and spline transformations give an RMS of nearly zero or zero; however, this does not mean that the image will be perfectly georeferenced.

http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Georeferencing_a_raster_dataset

Georeferencer

exercício 1

Vai-se georreferenciar a **Folha nº 592 da Carta Militar de Portugal** à escala 1:25.000, **3ª edição** (2005).

A Folha nº 592 foi previamente *scannerizada* num equipamento de dimensões adequadas, por forma a obter-se um único ficheiro *.tif com a imagem.

Optou-se por se trabalhar em **WGS84 UTM zone 29N**, ou seja, **EPSG 32629**.

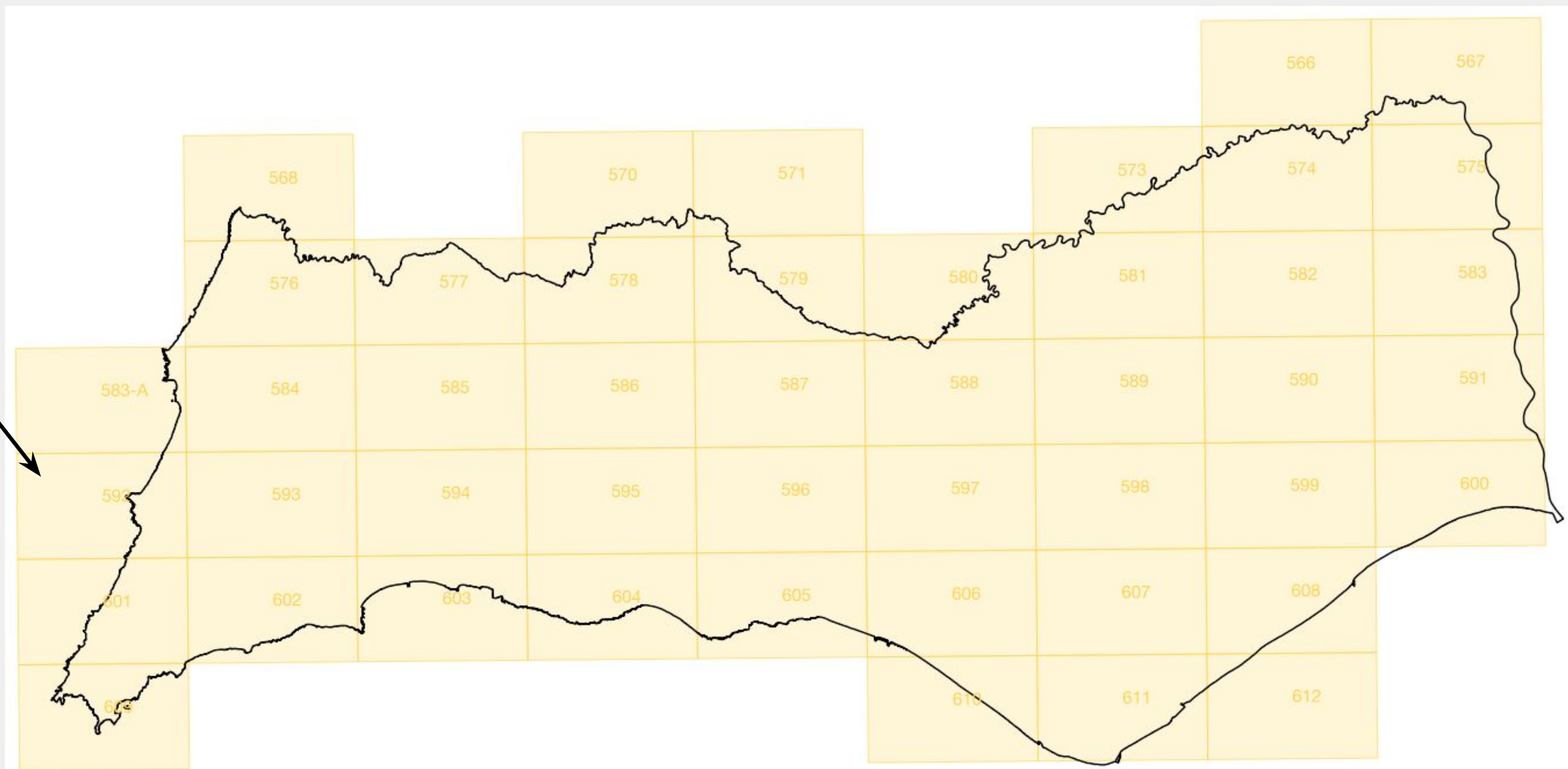
EPSG Code: 32629

WGS84 / UTM zone 29N

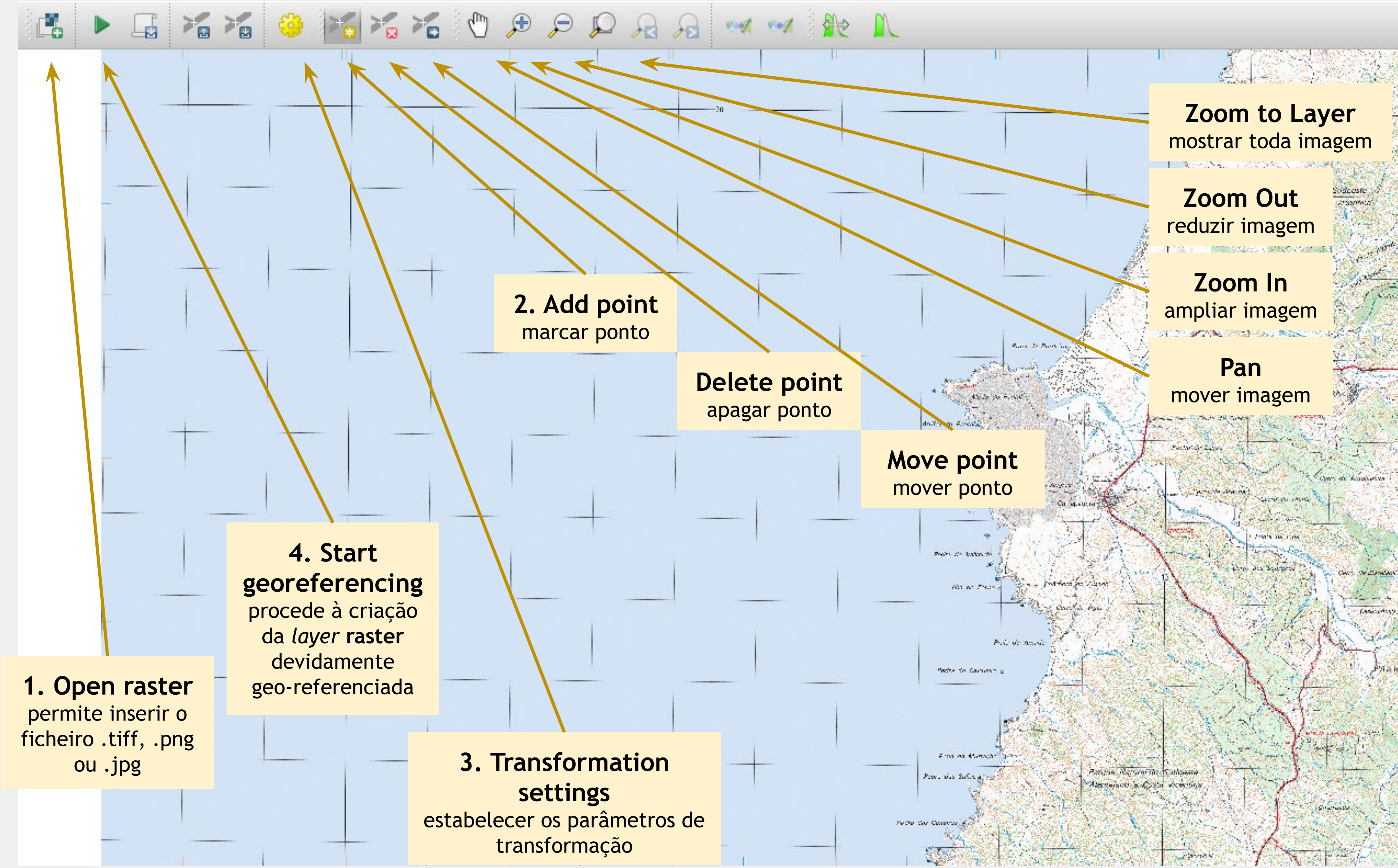
Area of Use: Between 12°W and 6°W, northern hemisphere between Equator and 84°N, onshore and offshore.
Scope: large and medium scale topographic mapping and engineering survey.

http://www.epsg-registry.org/

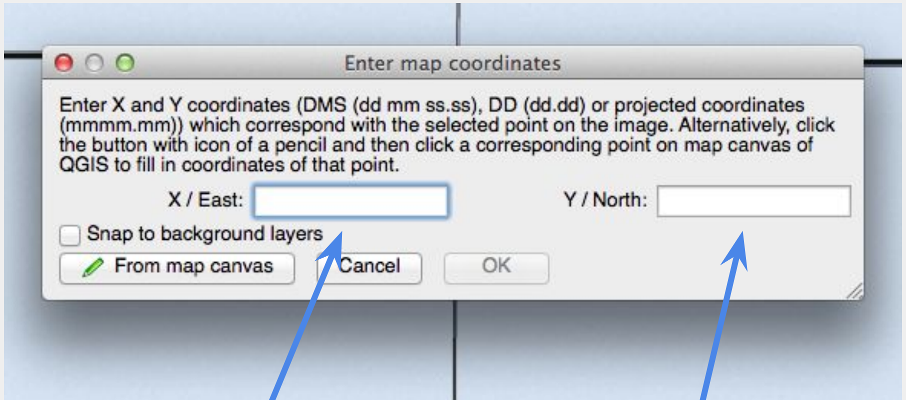
592



Plugin Georeferencer : janela principal



Plugin **Georeferencer** : georreferenciação



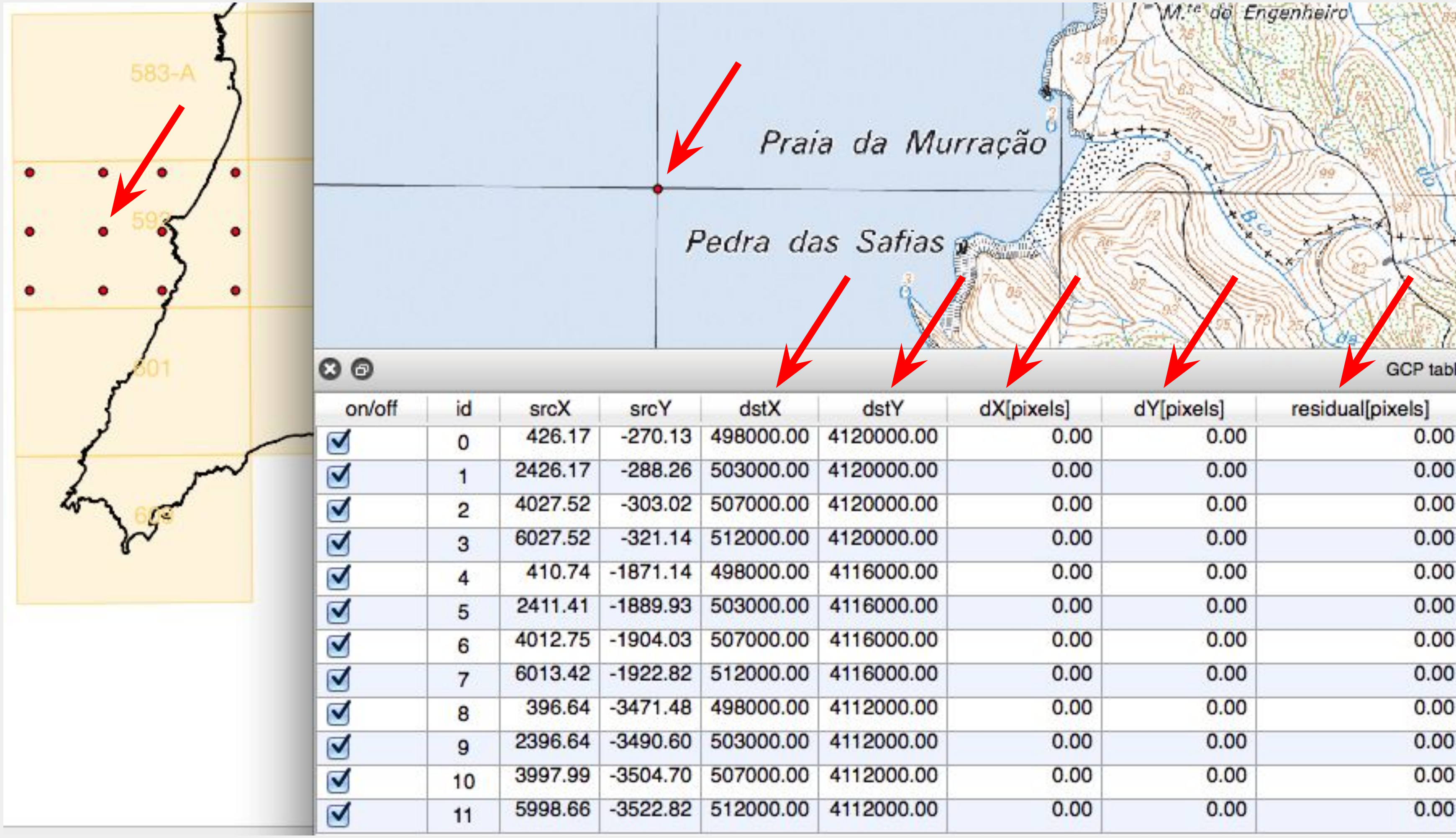
coordenada UTM WGS84 em X

coordenada UTM WGS84 em Y

sempre coordenadas métricas, ou seja com 7 dígitos

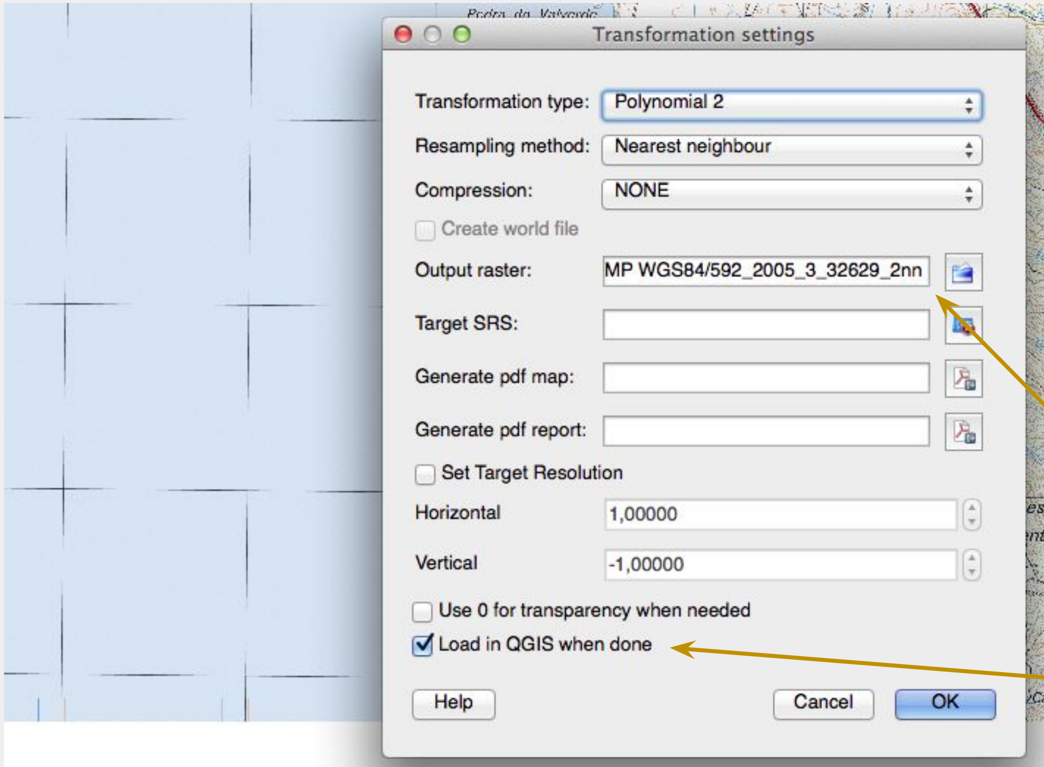
A georreferenciação começa com a marcação de pontos de controlo, na imagem, para os quais se conhecem previamente as coordenadas (***Ground Control Points***), no CRS estabelecido para a própria imagem e para a *layer* raster em criação.

As coordenadas podem ser atribuídas com base em diversos critérios, nomeadamente por comparação, por prévia identificação, ou por utilização de coordenadas já assinaladas na imagem. Neste exercício recorre-se à grelha UTM WGS84 desenhada na Folha, **e que corresponde ao EPSG do projecto**.



on/off	id	srcX	srcY	dstX	dstY	dX[pixels]	dY[pixels]	residual[pixels]
☑	0	426.17	-270.13	498000.00	4120000.00	0.00	0.00	0.00
☑	1	2426.17	-288.26	503000.00	4120000.00	0.00	0.00	0.00
☑	2	4027.52	-303.02	507000.00	4120000.00	0.00	0.00	0.00
☑	3	6027.52	-321.14	512000.00	4120000.00	0.00	0.00	0.00
☑	4	410.74	-1871.14	498000.00	4116000.00	0.00	0.00	0.00
☑	5	2411.41	-1889.93	503000.00	4116000.00	0.00	0.00	0.00
☑	6	4012.75	-1904.03	507000.00	4116000.00	0.00	0.00	0.00
☑	7	6013.42	-1922.82	512000.00	4116000.00	0.00	0.00	0.00
☑	8	396.64	-3471.48	498000.00	4112000.00	0.00	0.00	0.00
☑	9	2396.64	-3490.60	503000.00	4112000.00	0.00	0.00	0.00
☑	10	3997.99	-3504.70	507000.00	4112000.00	0.00	0.00	0.00
☑	11	5998.66	-3522.82	512000.00	4112000.00	0.00	0.00	0.00

Neste exercício marcaram-se 12 pontos, introduzindo para cada um deles as respectivas coordenadas UTM WGS84.
Na janela do **Georeferencer** e também na do QGIS os **pontos** ficam assinalados a **vermelho**.
Em simultâneo, vai-se constituindo a **tabela dos pontos de georreferenciação (GCP table)**.
Aí, as colunas **dstX** e **dstY** apresentam as coordenadas que foram sendo introduzidas. As colunas **dX**, **dY** e **residual** estão inicialmente a zeros porque não foi ainda parametrizado o modelo de transformação.



on/off	id	srcX	srcY	dstX	dstY	dX[pixels]	dY[pixels]	residual[pixels]
✓	0	425.34	-270.49	498000.00	4120000.00	-0.03	-0.21	0.21
✓	1	2426.10	-288.69	503000.00	4120000.00	0.10	0.02	0.10
✓	2	4027.01	-303.11	507000.00	4120000.00	-0.10	0.36	0.37
✓	3	6027.77	-322.08	512000.00	4120000.00	0.03	-0.17	0.18
✓	4	410.93	-1870.64	498000.00	4116000.00	-0.03	0.35	0.35
✓	5	2411.68	-1889.61	503000.00	4116000.00	0.10	-0.31	0.32
✓	6	4012.59	-1904.02	507000.00	4116000.00	-0.10	-0.07	0.12
✓	7	6013.35	-1922.23	512000.00	4116000.00	0.03	0.03	0.04
✓	8	395.75	-3471.93	498000.00	4112000.00	-0.03	-0.04	0.05
✓	9	2396.51	-3490.14	503000.00	4112000.00	0.10	-0.07	0.12
✓	10	3997.42	-3504.55	507000.00	4112000.00	-0.10	0.07	0.12
✓	11	5998.18	-3522.76	512000.00	4112000.00	0.03	0.04	0.05

Depois de ester estabelecido o modelo de transformação, as colunas **dX**, **dY** e **residual** preenchem-se automaticamente, informando da qualidade da transformação.

No caso das **Folhas da CMP** uma transformação de tipo **Polynomial 2**, conjugada com um método de **Nearest neighbour**, proporciona óptimos resultados.

Output raster
nome e local (pasta) de armazenamento do(s) ficheiro(s) que correspondem à *layer* ***raster*** em criação

Load in QGIS when done
a *layer* ***raster*** depois de criada pode ser adicionada automaticamente ao projecto QGIS

A decisão sobre os **tipo** e **método** de **transformação** é decisiva para a qualidade final da georreferenciação em curso.

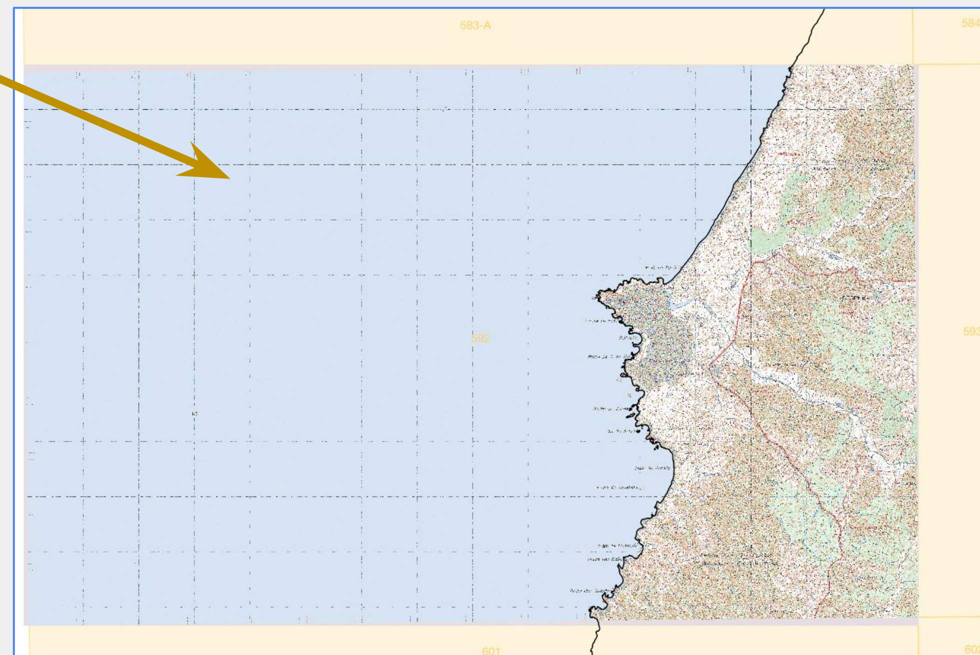
Por isso, nunca deve ser descurada toda a atenção e reflexão durante a tomada de tais decisões...

Plugin **Georeferencer** : criação da nova *layer* **raster**

A nova *layer* raster foi então adicionada automaticamente ao projecto QGIS!

Para além do novo ficheiro ***.tif** que é criado e que contém a layer *raster*, e de um ficheiro auxiliar de georreferenciação (***.tif.aux.xml**), pode ou não ser criado um **ficheiro de pontos de georreferenciação** (***.points**). Este último ficheiro será particularmente útil se for necessário repetir os procedimentos de georreferenciação adicionando mais pontos, corrigindo as coordenadas de um ou mais pontos, apagando pontos ou, ainda, alterando os **tipo e método de transformação**.

Os botões **Load GCP points** e **Save GCP points as** permitem utilizar ficheiros de pontos anteriormente gravados, e permitem gravar ou alterar ficheiros de pontos de controlo….



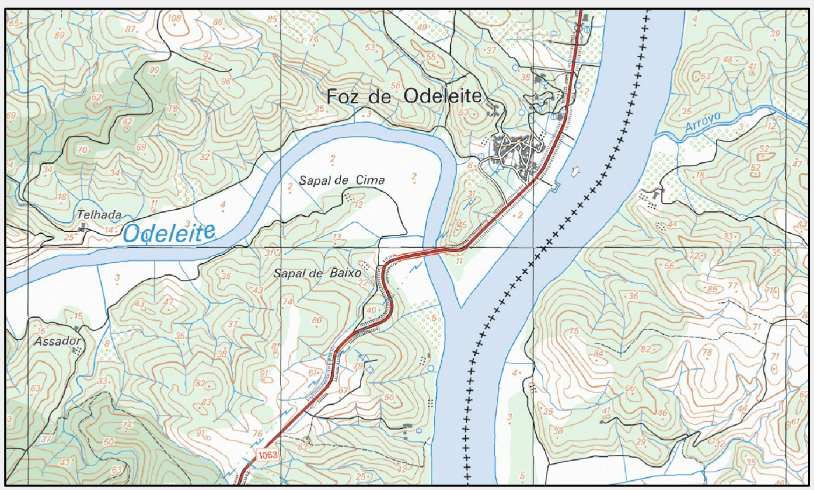
MAIS INFORMAÇÃO DISPONÍVEL EM:
http://www.qgis.org/en/docs/user_manual/plugins/plugins_georeferencer.html?highlight=georeferencer

Georeferencer

exercício 2

No segundo exercício vai-se georreferenciar uma fotografia aérea feita pela **FAP - Força Aérea Portuguesa** em 1985 sobre o Rio Guadiana, com a povoação de Foz de Odeleite, a Ribeira de Odeleite, etc. visíveis e facilmente identificáveis.

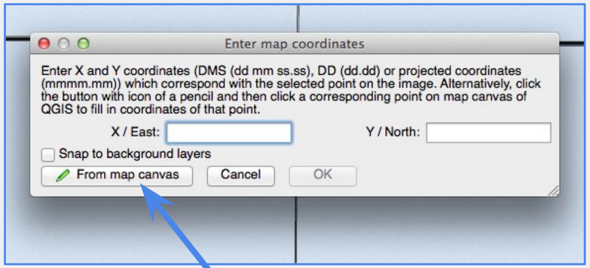
A tarefa obriga a cuidados na identificação dos pontos de controlo e também à adopção do **Polynomial 3 algorithm** como **TIPO DE TRANS-FORMAÇÃO** e do **MÉTODO Nearest Neighbour**.



A Folha nº 583 da CMP à escala 1:25.000 serve de base para georreferenciar a fotografia aérea...

A fotografia aérea já com os pontos de controlo assinalados.

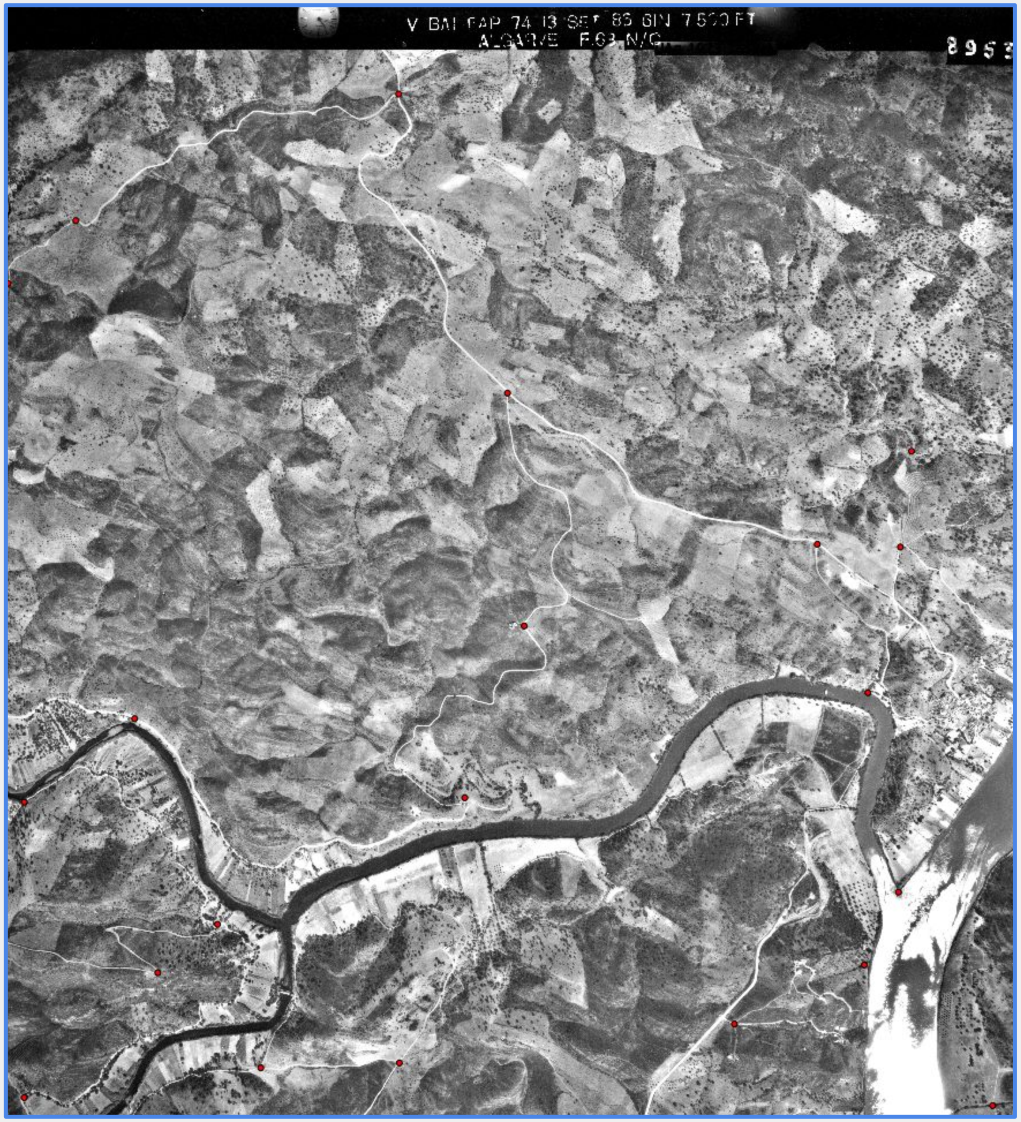
Aqui, ao contrário do exercício de georreferenciação da Folha da CMP, os pontos de controlo estão baseados em pontos relevantes do território, seja natural seja humanizado. Esses pontos são depois assinalados na Folha da CMP e assim obter-se-ão as coordenadas...

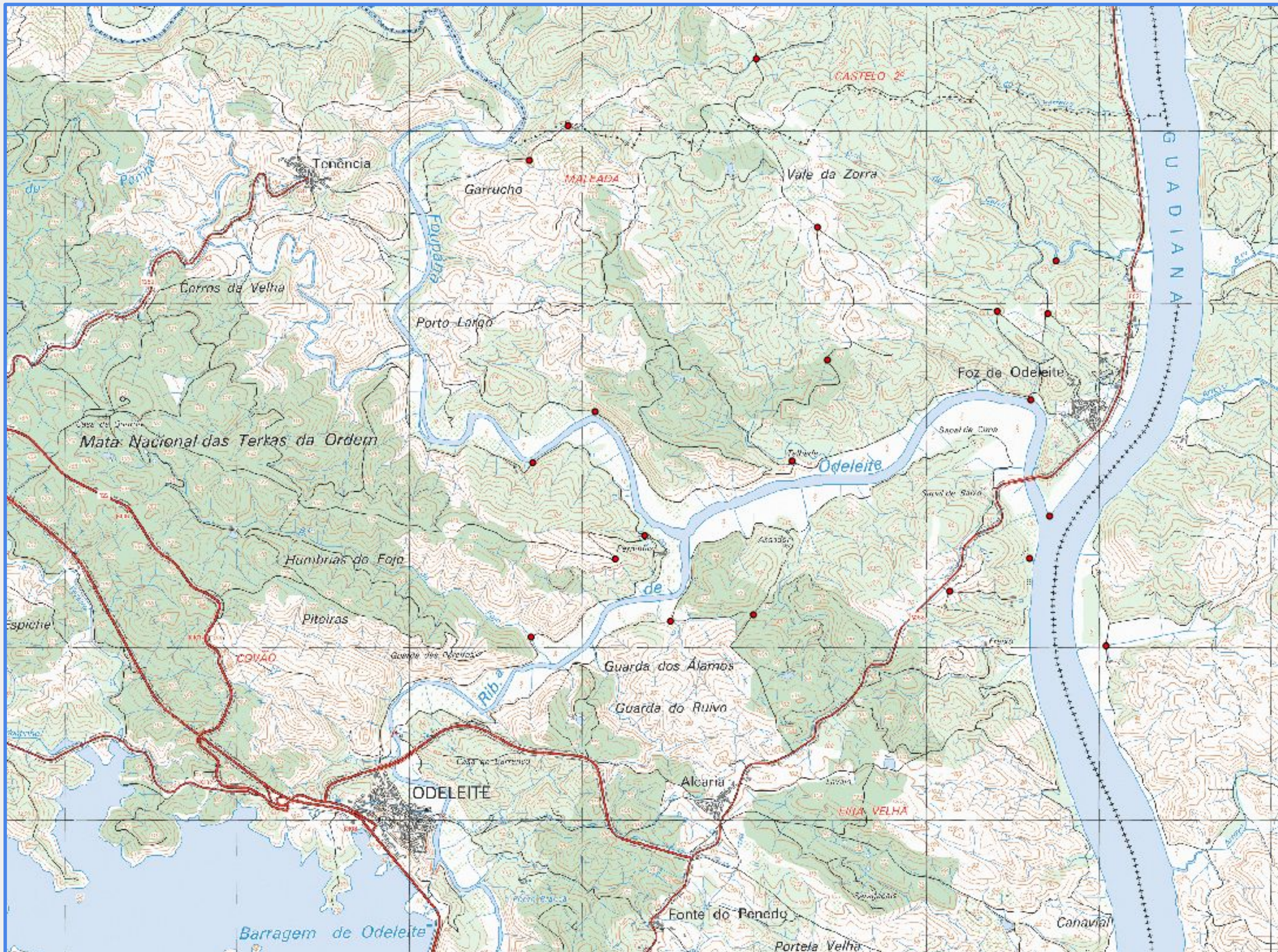


Em vez de serem introduzidas as coordenadas X e Y nas respectivas janelas, utiliza-se o botão **From map canvas**.

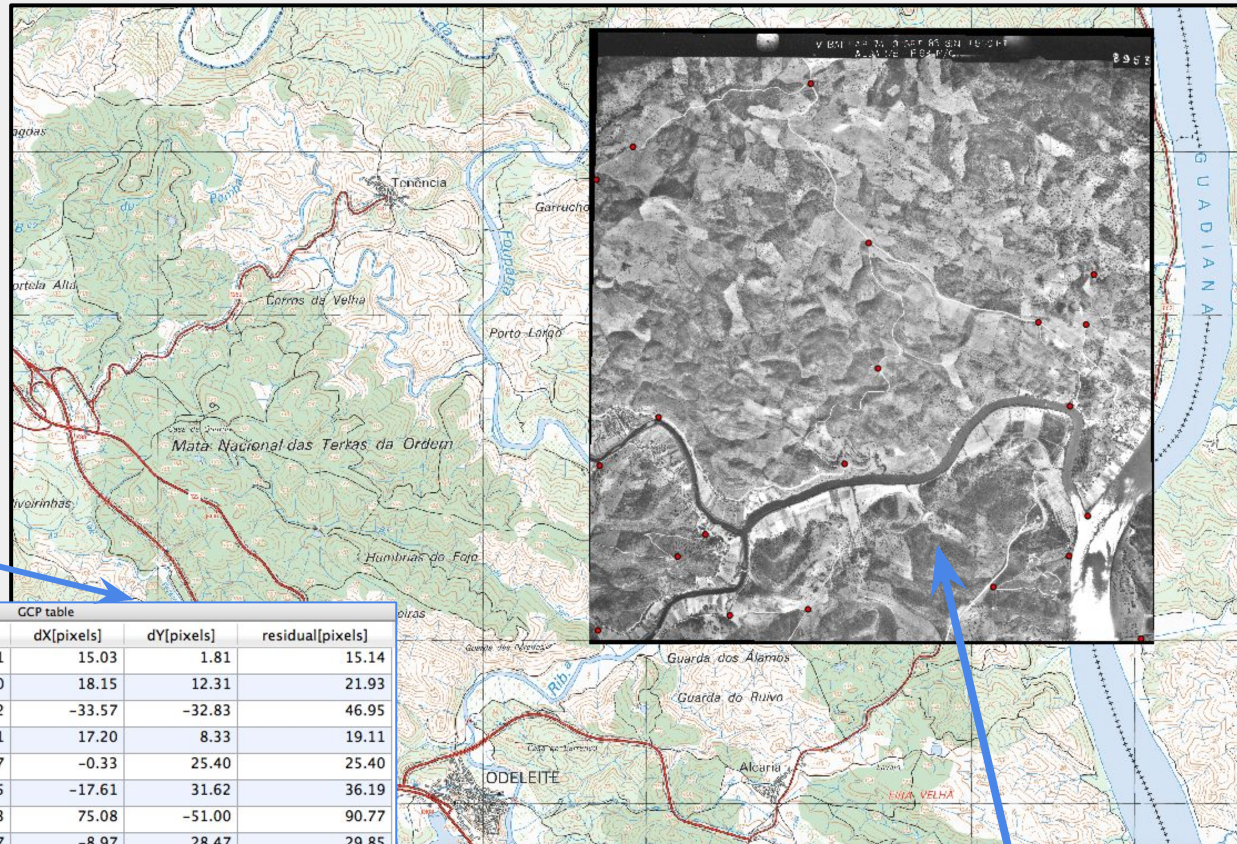
Os pontos são inicialmente assinalados na fotografia aérea e depois na Folha da CMP...

Estão assinalados 21 pontos de controlo, tão distribuídos pela fotografia aérea quanto possível.




Tenência
Garrucho
MALEADA
Vale da Zorra
CASTELO
GUADIANA
Corros da Velha
Porto Largo
Foz de Odeleite
Mata Nacional das Terras da Ordem
Odeleite
Humbrias do Fojo
Pitoiras
Espiche
Guarda dos Álamos
Guarda do Ruivo
Alcaria
ODELEITE
Fonte do Penedo
Barragem de Odeleite
Portela Velha
Canavial

A tabela de pontos de controlo para a georreferenciação, já com as estatísticas resultantes do modelo de georreferenciação **Polynomial 3** e **Nearest neighbour**.

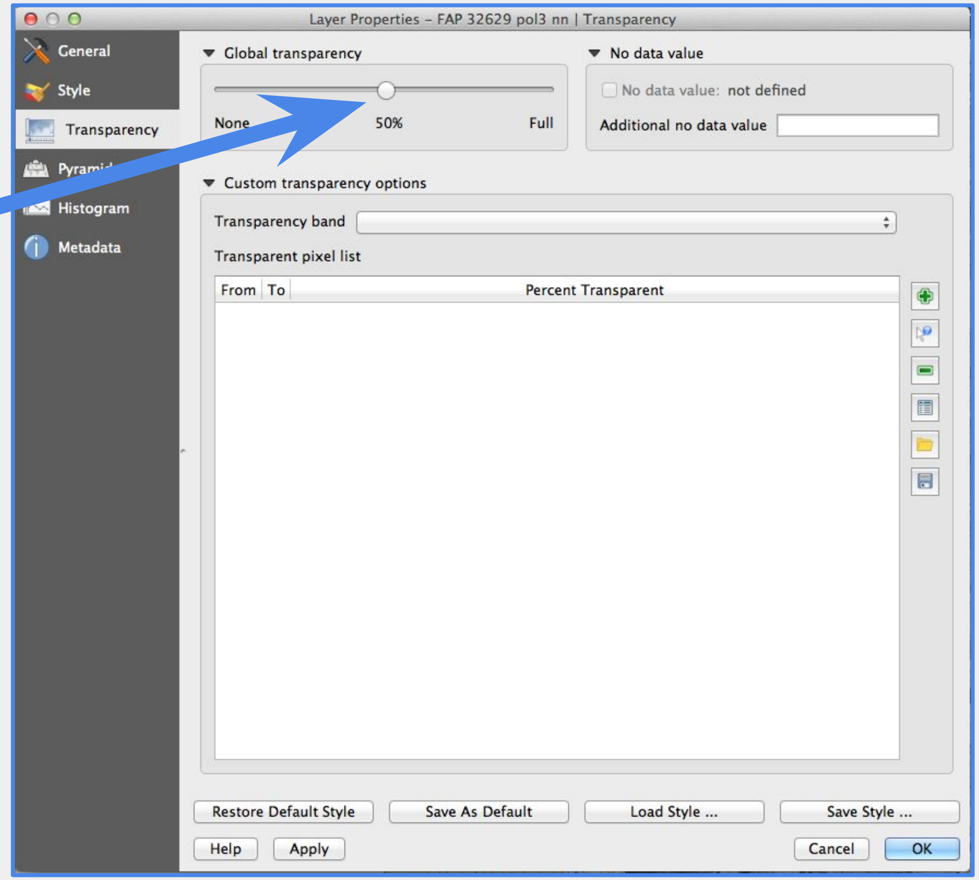


GCP table

on/off	id	srcX	srcY	dstX	dstY	dX[pixels]	dY[pixels]	residual[pixels]
☑	0	8386.98	-8360.86	637710.07	4134766.71	15.03	1.81	15.14
☑	1	8099.00	-6480.86	637601.02	4135441.50	18.15	12.31	21.93
☑	2	7620.85	-5081.72	637406.76	4135956.12	-33.57	-32.83	46.95
☑	3	8509.24	-4204.20	637747.56	4136249.21	17.20	8.33	19.11
☑	4	3676.10	-838.12	636009.46	4137421.57	-0.33	25.40	25.40
☑	5	1968.61	-8663.78	635361.94	4134654.25	-17.61	31.62	36.19
☑	6	1406.24	-9120.20	635191.53	4134517.93	75.08	-51.00	90.77
☑	7	2376.13	-10016.73	635511.89	4134156.67	-8.97	28.47	29.85
☑	8	3682.89	-9970.55	635992.42	4134194.16	6.03	-31.42	31.99
☑	9	6839.78	-9603.78	637130.71	4134330.48	-30.85	-44.39	54.06
☑	10	8065.04	-9046.85	637594.20	4134521.33	14.01	-10.80	17.69
☑	11	9274.01	-10372.63	638037.25	4134013.54	-8.39	41.12	41.97
☑	12	8404.64	-5107.53	637699.85	4135942.49	-10.95	-23.78	26.18
☑	13	4701.68	-3656.77	636363.90	4136443.47	-4.01	23.97	24.30
☑	14	4859.25	-5851.92	636421.84	4135673.25	11.62	7.78	13.98
☑	15	4299.60	-7471.12	636217.35	4135087.07	10.43	23.82	26.00
☑	16	633.32	-2030.79	634917.19	4137033.06	-1.69	-14.51	14.61
☑	17	-5.12	-2623.04	634692.26	4136831.98	15.94	-22.65	27.70
☑	18	1187.54	-6725.37	635073.96	4135373.34	-48.30	-7.82	48.93
☑	19	148.37	-7511.87	634712.71	4135076.84	-5.82	31.53	32.07
☑	20	147.02	-10297.92	634702.48	4134064.66	-13.01	3.04	13.36

A fotografia após a georreferenciação, já transformada em ***layer raster*** e sobre a Folha da CMP, no QGIS…

Polynomial 3
Nearest Neighbour



a regulação da % de transparência ajuda a analisar a qualidade da georreferenciação...


Polynomial 3
Nearest Neighbour
CASTELO
MALEADA
Vale da Zorra
Garrucho
Foupana
Porto Largo
GUADIANA
Foz de Odeleite
Sapal de Cima
Telhado
Odeleite
Sapal de Baixo
Assador
Pernadas
do Fojo
Guarda das Pereiras
Guarda dos Álamos
Freixo

Thin Plate Spline
Cubic


Thin Plate Spline
Cubic
CASTELO 2º
MALEADA
Vale da Zorra
Garrucho
Foupana
Porto Largo
G U A D I A N A
Foz de Odeleite
Sapal de Cima
Telhada
Odeleite
Sapal de Baixo
Assador
Pernadas
do Fojo
Guarda das Pereiras
Guarda dos Álamos
Freixo
Arroyo

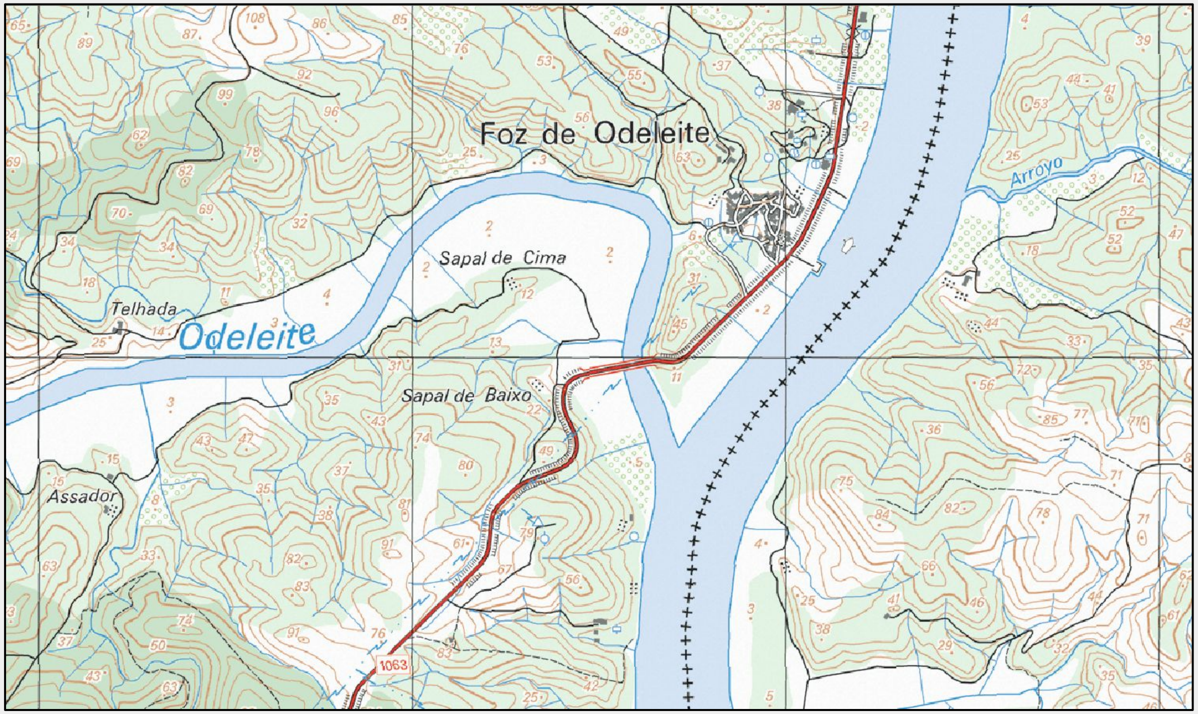
27

Georeferencer

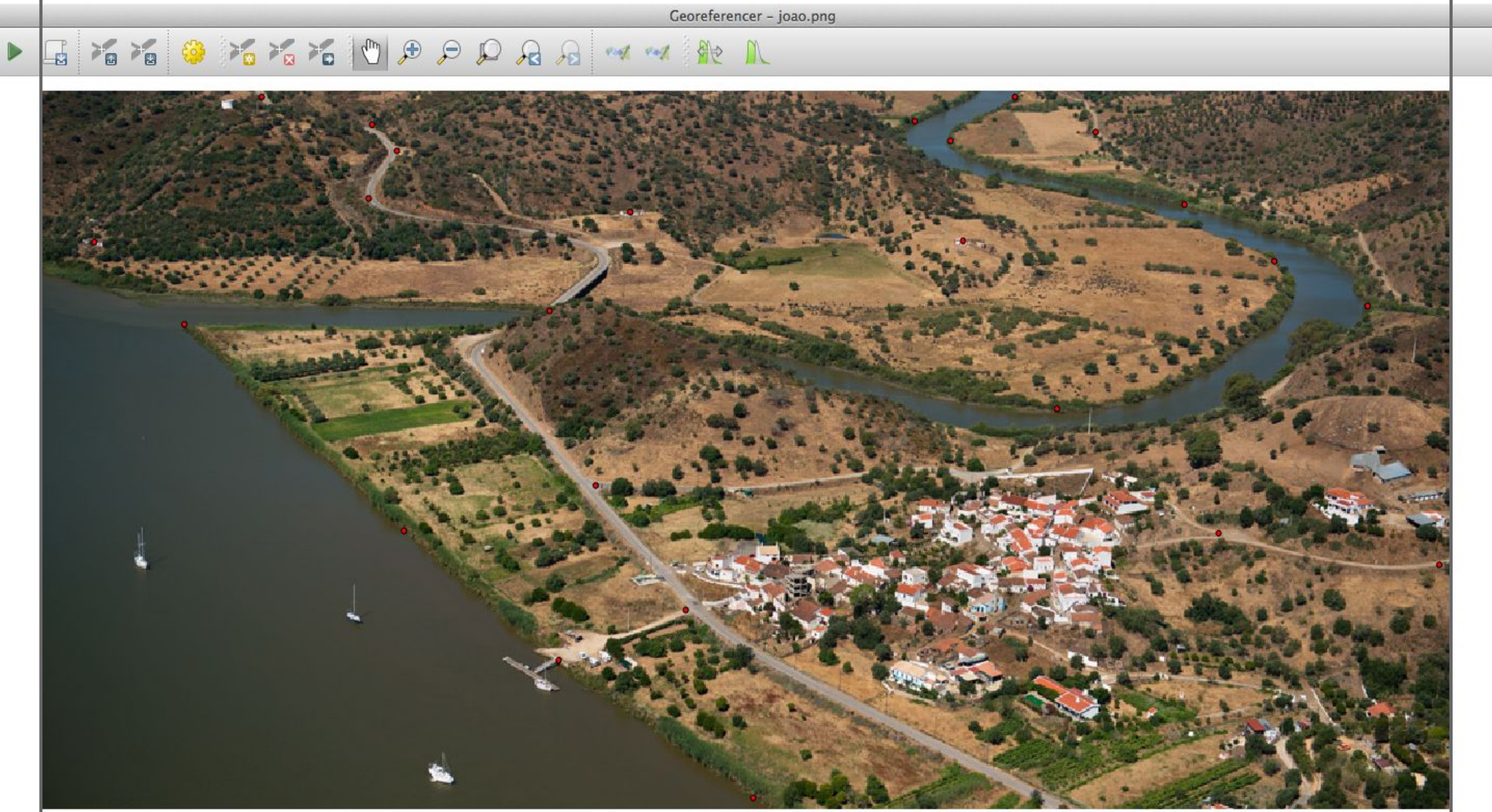
exercício 3

No terceiro exercício é georreferenciada uma fotografia oblíqua sobre o Rio Guadiana, com a povoação de Foz de Odeleite e a Ribeira de Odeleite.

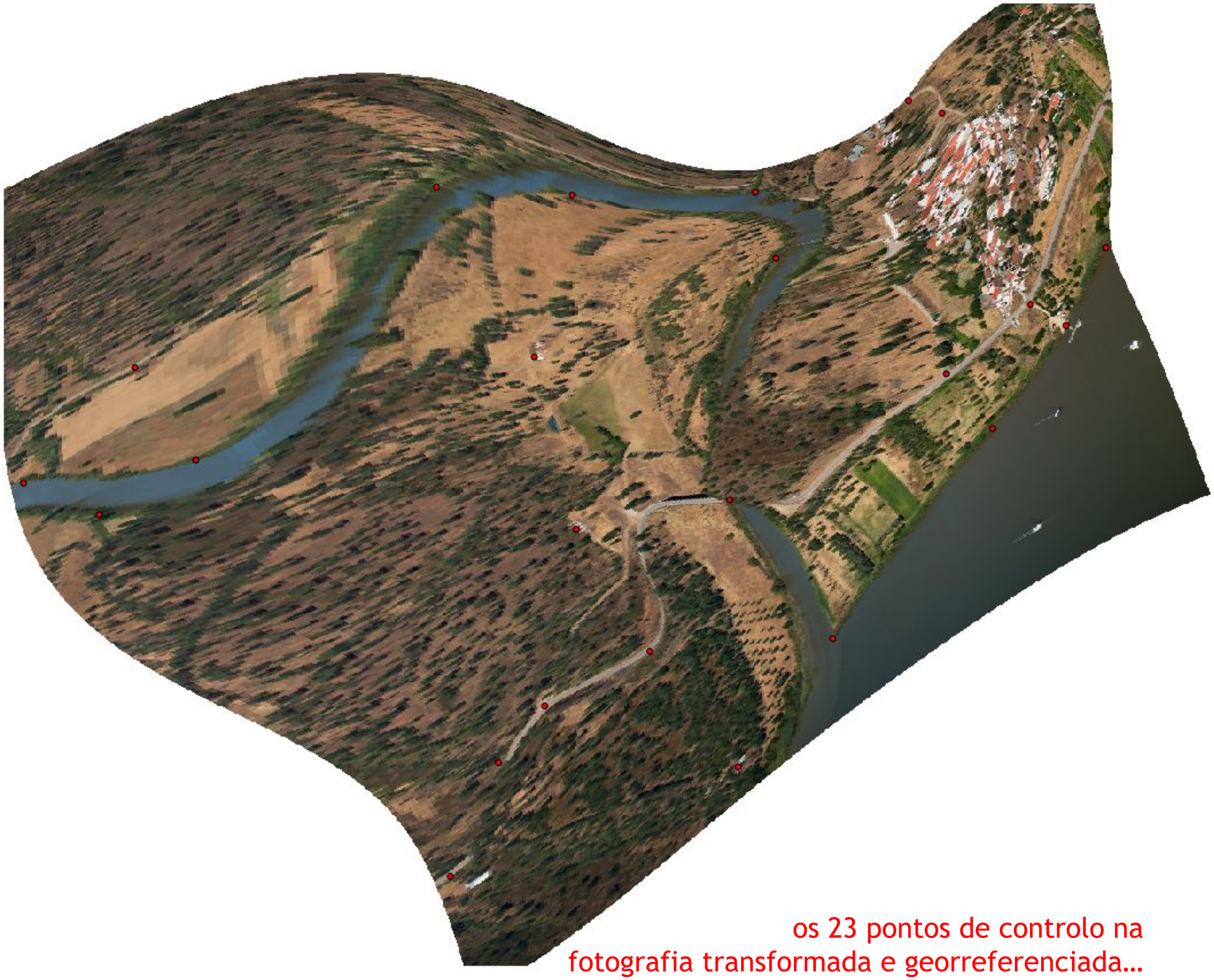
A tarefa é mais exigente porque a forma como a fotografia está registada obriga a um maior cuidado na identificação dos pontos de controlo para georreferenciação e também à adopção do **Thin Plate Spline (TPS) algorithm** como **TIPO DE TRANSFORMAÇÃO** e do **MÉTODO Cubic**.



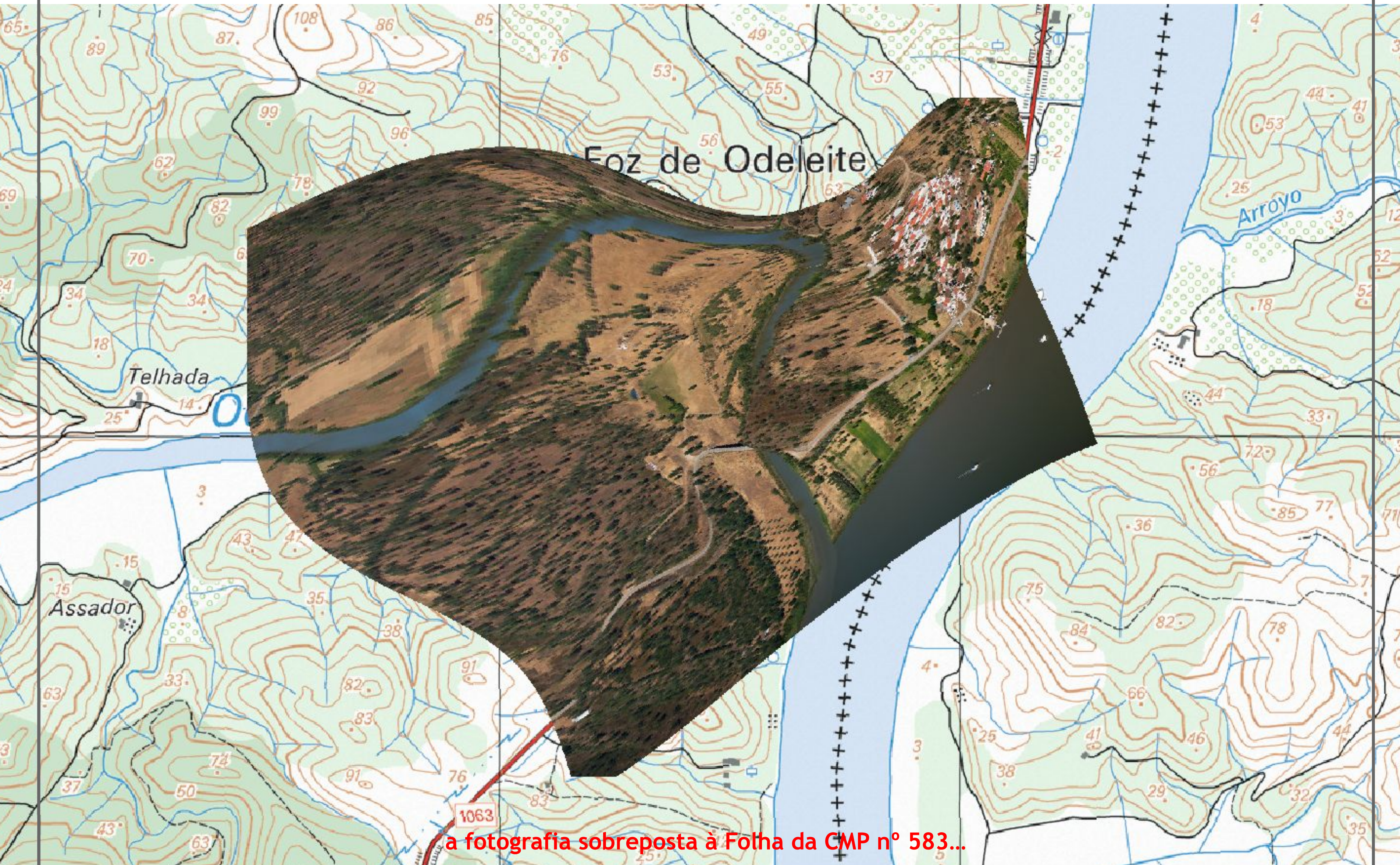
A Folha nº 583 da CMP à escala 1:25.000 serve de base para georreferenciar a fotografia...



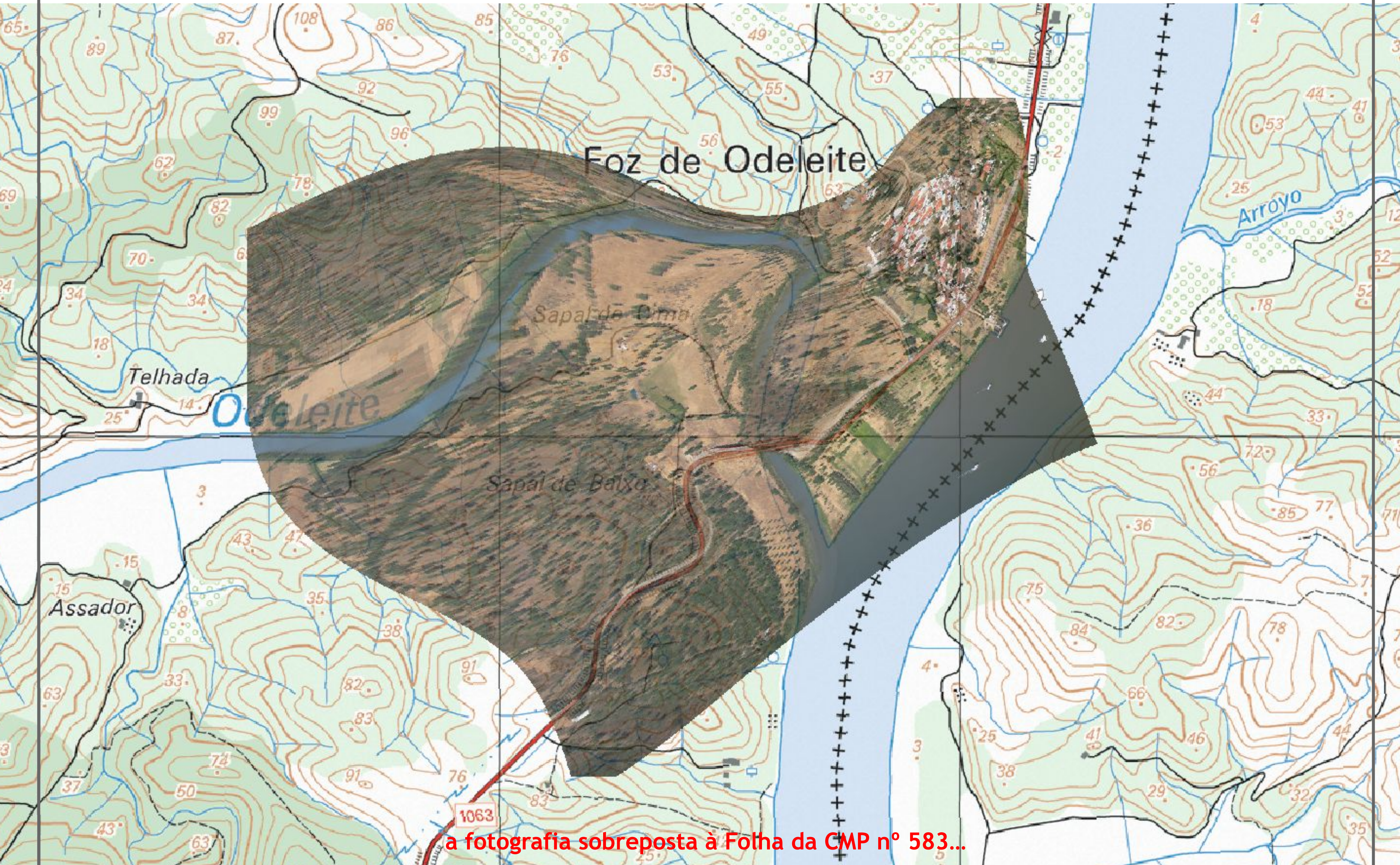
os 23 pontos de controlo…



os 23 pontos de controlo na
fotografia transformada e georreferenciada…



a fotografia sobreposta à Folha da CMP nº 583…



a fotografia sobreposta à Folha da CMP nº 583…