IV

Comparison between two techniques of line-drawing migration (ray tracing and common tangent method)

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IV.A. - INTRODUCTION

Deep seismic sections are often interpreted on the basis of unmigrated data. Numerical migration is applied only at the very end of classic processing procedures, yielding results which are generally disappointing or ambiguous at great depth due to the very weak signal/noise ratio [Warner, 1987]. However, for the ECORS-CROP Alpine traverse as well as the ECORS Jura-Bresse segment – where certain reflectors are probably steeply dipping – it was considered necessary to work on depth migrated cross-sections in order to avoid serious errors in the interpretation. In particular, this is a prerequisite for constructing balanced crustal sections.

The experience gained from the interpretation of deep seismic sections had led to an efficient method, which

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Fig. IV-1. - Migration using ray tracing (RT).
A) Velocity model used for ray tracing. 1 = Cenozoic (4.0 km.s\(^{-1}\)); 2 = Mesozoic (5.0 km.s\(^{-1}\)); 3 = Palaeozoic and Mesozoic of the Po Plain (5.8 km.s\(^{-1}\)); 4 = upper crust (6.0 km.s\(^{-1}\)); 5 = lower crust (6.8 km.s\(^{-1}\)); 6 = Ivrea body (7.8 km.s\(^{-1}\)).
B) Picking decision used for migration.
C) Results of migration, with filtering to eliminate reflections having dips steeper than 60°.

Fig. IV-2. - Migration par tracé de rayons (RT).
A) Segments sélectionnés pour la migration.
B) Modèle de vitesse utilisé pour le lancer de rayons. 1 = Cénozoïque (4.0 km.s\(^{-1}\)); 2 = Mésozoïque (5.0 km.s\(^{-1}\)); 3 = Paléozoïque et Mésozoïque de la Plaine du Po (5.8 km.s\(^{-1}\)); 4 = croûte supérieure (6.0 km.s\(^{-1}\)); 5 = croûte inférieure (6.8 km.s\(^{-1}\)); 6 = corps d’Ivrea (7.8 km.s\(^{-1}\)).
C) Résultats de la migration, avec filtrage pour éliminer les réflexions qui ont des pente supérieurs à 60°.
IV.B. - Migration based on ray tracing

The picked events used in this study [Truffert, 1989; Guellec et al., 1990; Truffert et al., 1990] constitute about 3,000 reflections distributed throughout the length of the ECORS Jura-Bresse profile as well as the ECORS-CROP profile across the Alps (fig. IV-1 B). The choice was restricted to the highest amplitude reflections, having lengths of more than about 50 m. With the exception of a few particular details – notably, consideration of mantle reflections beneath the Jura – this selection corresponds to the events finally picked out by the profile working group.

After digitization, each reflection was migrated using the RAYMIG program [Reynaud, 1988], which is available at the IFP. This program is based on the tracing of rays in a two-dimensional medium (with vertical and lateral variations in velocity). So it therefore takes the refraction of rays into account. Consequently, it is necessary to define a preliminary velocity distribution along the entire length of the section. This is an important and difficult step, even if an attempt is made to link up with the results of experimental seismics.

Figure IV-1b was largely constructed by considering, at least within the internal zones, an interpretative gravimetric section. The velocities of the non-sedimentary units were calculated using a standard relation [Perrier and Ruegg, 1973]. In the external zones, velocities were adopted for the upper crust, lower crust and mantle, which are very distinct. The sedimentary units of the Bresse plain, Jura and Molasse Basin were assigned an overall mean velocity, which is in agreement with the work of Bergerat et al. [1990]. In order to be able to analyse the data in two-dimensions, treatment of the selected reflections by RAYMIG was carried out assuming a null value for $\beta$, the angle between the profile direction and the main dip direction of structures.

For a certain number of reflections, in particular those situated in the Penninic zone or in the deep mantle beneath the Jura-Bresse region, there is an important distortion effect produced by ray tracing (RT), which leads to the appearance of pronounced curvature (fig. IV-2). The concave-upwards cups produced in this way are classic artefacts of the treatment used in migration. These cups are easily removed in the present study by means of appropriate filters, but this is a drastic process which is partly arbitrary in nature. An example of this type of filtering is given in figure IV-1c, in which only those reflections with dips less than 60° are retained after migration.

IV.C. - Migration using the common tangent method

A second attempt at migration was carried using the common tangent method (CTM) [Sénéchal, 1989; Thouvenot et al., 1990; Sénéchal and Thouvenot, 1991]. Taking a highly simplified view of the problem, an unmigrated seismic section is considered as a plane in which the mean velocity between the surface and each reflector is variable in both the vertical and lateral direction. Thus, we can assume that a given reflector of very small size is located in a medium which locally has a constant mean velocity. For each of the extremities of the reflector, the geometrical locus of all possible dip values defines an arc which is centered at a point on the surface vertically above the respective extremity. The migrated position is obtained by constructing the tangent common to both arcs.

This technique assumes that variations in velocity distribution are regular. In particular, it should be ascertained whether the mean velocity between the surface and the reflector is fairly similar to the value obtained before mi-

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**Fig. IV-2.** Unprocessed result from RT migration, without dip filtering (cf. fig. IV-1 C).

**Fig. IV-2.** Résultats bruts de la migration par rayons, sans filtrage des pendages (cf. fig. IV-1 C).

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Fig. IV.3. – Picking decision used for migration based on the common tangent method (CTM).

Fig. IV.3. – Segments sélectionnés pour la migration basée sur la méthode de la tangente commune (CTM).
Fig. IV.4. - Velocity grid used for CTM migration.

Fig. IV.4. - Grille des vitesses utilisées pour la migration CTM.
Fig. IV-6. – CTM migration:
  a) Massif Central-Bresse Plain-Jura-Alpine foreland.
  b) Foreland-Alps-Po Plain.
proportion of the lower crust. The calibration at depth of the main horizons is generally closely comparable. On the RT migration, deep structures beneath the Bresse plain continue to display a pull-down effect which is less marked on the CTM migration. Beneath the Jura, the CTM migration reveals the presence of wedge-shaped structures situated at depths of less than 10 km. A sudden deepening of the Moho is seen beneath the Subalpine ranges on the RT migrated section, although such an effect does not appear on the CTM migration. In part, this is due to problems caused by the linking up of profiles ALP2 and ALP1 (at km 140). Through a careful consideration of the surface topography, the CTM migration shows a basement step at this location, with the SE block lying 2-3 km above the NW block. Since the two profiles are relayed here en echelon, with a lateral offset of about 10 km, it is difficult to discern any possible dip across this break in level. It is nevertheless possible that such a structure may represent a slice of Subalpine basement which is more external than the main Belledonne thrust slice.

The shear zone situated at the bottom of this main thrust slice has a different appearance on each of the migrated sections. The more interpretative RT picking decision tends to generate a larger number of reflections. The CTM migration shows only a slight increase in reflectivity at this point, even if some other zones actually appear locally more reflective. On the other hand, the characteristic shape of the southeastern bottom of the Belledonne slice — highly transparent at this point — is to be found on both migrations. Immediately beneath the reflections of the Penninic front, a notch is seen in the Belledonne slice which suggests a possible underthrust structure.

By contrast, the RT migration has difficulty in sorting out the interdigitation of reflectors beneath the Vanoise and Grand Paradis massifs. In this segment, on the contrary, the CTM migration reveals several reflective horizons with an anticlinal form beneath the Grand Paradis. The dominant impression here is that of internal units which were being thrust towards more external parts of the belt and which were blocked by a rigid wedge made up of External Crystalline Massifs. In this case, we are dealing with a clear example of "crocodile tectonics".

IV.E. — Conclusions

Except for the ALP 1-ALP 2 boundary, where out-of-the plane lateral events could have disturbed the signal, most of the ECORS-CROP profiles are orthogonal to major structural trends. However, explosive shots have locally provided evidence of oblique dips of reflectors compared to the studied profile (see Chap. II.3).

Unlike in the Swiss studies (Stauble et al., 1993; Litak et al., 1993), no 3D effects has been taken into account for the proposed migrations.

From the two attempts at migration presented here, we may conclude that, when migrating sections with elementary geometrical techniques, it is essential to avoid the excessive interpolation or extrapolation of reflections. It is probable that more objective results can be obtained by only picking reflections in localized areas where a high amplitude signal is actually present. Both these methods are evidently very quick to implement, and they also show the advantage of providing depth sections which can be used directly, in particular for the construction of balanced cross-sections.

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