*GOCAD ENSG Conference*
*3D Modeling of Natural Objects : A Challenge for the 2000's*
*4 - 5 June 1998*

# Is seismic demigration equivalent to forward modeling?

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**Abstract**

Kirchhoff-type, isochrone-stack demigration is the natural asymptotic inverse to classical Kirchhoff or diffraction-stack migration. Both stacking operations can be performed in true amplitude by an appropriate selection of weight functions. As Kirchhoff migration is usually understood as the inverse process to Kirchhoff modeling, the natural question arises whether Kirchhoff demigration is identical to seismic forward modeling. The answer is that it is not, but these processes are closely enough related to enable the use of demigration for modeling purposes. All that has to be done is to implicitly construct a depth section as if obtained from a previous true-amplitude Kirchhoff migration.

## Introduction

To transform a given time section into a depth-migrated section in which the migrated seismic pulses along the reflectors are free from geometrical-spreading losses, one may employ true-amplitude Kirchhoff-type (or diffraction-stack) depth migration (see, e.g., Bleistein, 1987; Schleicher et al., 1993; Sun and Gajewski, 1997). Neglecting all other factors that affect seismic amplitudes (Sheriff, 1975) and ignoring multiple arrivals, the true-amplitude, depth-migration output at each point of a reflector is a measure of the reflection coefficient. This coefficient pertains to the primary-reflection ray joining the source to the receiver position in the given measurement configuration. The considered point on the reflector is the specular reflection point of this ray.

The Kirchhoff migration integral is often understood, in an asymptotic sense, as the inverse operation to the classical Kirchhoff integral. In the same way as the Kirchhoff integral can be used to propagate a given incident wavefield from the reflector location to the receiver point, the Kirchhoff migration integral serves to reconstruct the Huygens' secondary sources along the reflector in position and strength from the measured wavefield at several receiver positions along the seismic line.

Most recently, a new process has been introduced in seismic reflection imaging being called *seismic demigration.* It has been discussed in more detail by Hubral et al. (1996) and mathematically described by Tygel et al. (1996). It has been designed as the inverse process to seismic migration and is, thus, easily confused with *seismic forward modeling.* In this paper, we want to clarify in a simple way the similarities and differences of modeling and demigration. All three processes cannot be completely understood without talking about "true amplitudes," i.e., the correct treatment of geometrical-spreading effects. We will see that there exists a close relationship between seismic modeling and demigration, which needs to be understood and which we shortly want to elaborate.

For this purpose, we start by investigating in more detail the new process of seismic demigration. Technically, it is given by a stack to be performed on a depth-migrated section: In the same way as the Kirchhoff migrated section is constructed by stacking the original seismic data along certain model-based stacking surfaces (or lines in 2D) without the need to determine the location of the reflection traveltime surfaces in the seismic section, its inverse can be realized by a similar stack along related surfaces without knowing the location of the reflectors in the migrated section. The stacking surfaces are simply the isochrones, i.e, the surfaces of equal reflection traveltime between a given source and the corresponding receiver. These are also constructed on the given macrovelocity model without knowing the location of the reflectors in the migrated section.

The fact that the Kirchhoff migration integral seems to have two inverse integrals leads to the obvious question posed in the title of this paper: Are the two operations represented by these integrals identical? The answer is that, although closely related, the two processes are not identical. Let us elaborate on this in more detail in the next section.

## Modeling versus demigration

In this section, we will briefly discuss the terms "forward modeling" and "demigration" so as to clarify their meaning. We will, then, immediately recognize the similarities and differences between the concepts.

### Modeling

Modeling, as we understand it, means the analytical or numerical simulation of a physical process given all the equations and parameters for its complete description. In our case, the physical process to be simulated is seismic wave propagation. It is described, e.g., by the elastic or acoustic wave equation. The parameters that govern this process are the velocity and density distributions within the medium, the source and receiver locations, the source wavelet, as well as the appropriate boundary and initial conditions. Seismic forward modeling is, then, realized by an implementation of a solution to the appropriate wave equation or of a suitable approximation. In this way, one obtains a synthetic equivalent of the seismic data that would have been recorded if the very same experiment had been actually carried out in the field. For a layered model, we need, in particular, the location of the all transmitting and reflecting interfaces.

For reasons of comparison, we choose the well-known Kirchhoff integral to represent a seismic forward modeling scheme. It can be written as (Frazer and Sen, 1985; Tygel et al., 1994a)

$$K(\xi,t) = \frac{1}{2\pi} \iint_{\Sigma_R} dS\, W(\xi,P_R)\, \mathcal{R}(P_R)\, \partial_t F[t-\tau(\xi,P_R)]\ , \tag{1}$$

where $K(\xi,t)$ denotes the modeled synthetic seismogram and $z=\Sigma_R(x)$ is the reflector along which we have to integrate. Here, $\xi$ denotes the so-called configuration parameter (Bleistein, 1987; Schleicher et al., 1993) which locates the source-receiver pair, and $x$ is the horizontal coordinate of the depth points. Note that $\xi$ and $x$ are two-dimensional vectors or simply scalars for three- or two-dimensional modeling, respectively. In equation (1), the kernel or weight function $W(\xi,P_R)$ consists of an obliquity factor and two Green's function amplitudes. The latter pertain to the wave propagation along the two paths from the source $S(\xi)$ to the point $P_R=(x,z=\Sigma_R(x))$ on the reflector, and from there to the receiver $G(\xi)$. Moreover, $\mathcal{R}(P_R)$ denotes the specular plane-wave reflection coefficient of the incident wave at the reflector point $P_R$. Finally, $F[t]$ is the analytic pulse that is chosen to represent the source signature and

$$\tau(\xi,P_R) = T(S(\xi),P_R) + T(G(\xi),P_R) \tag{2}$$

is the sum of traveltimes along the two paths of propagation $SP_R$ and $GP_R$, where $S(\xi)$ and $G(\xi)$ are fixed and $P_R$ varies along the reflector. We remind that for layered media, an integral of the type of equation (1) has to be solved along each interface.

## Demigration

Demigration, on the other hand, uses a conceptually different approach. The aim of demigration is to reconstruct a seismic time section from a corresponding depth migrated section. In other words, demigration aims to invert the process of migration. Of course, as migration is aimed at inverting the wave propagation effects, it is related in a strong way to the wave equation. Observe, however, that migration algorithms are based on a wave equation that does not use the true velocity distribution in the Earth, but an approximate macrovelocity model that may be much simpler. Correspondingly, demigration, as the inverse process to migration, also uses, instead of the true, but generally unknown velocity distribution, the same macrovelocity model as used in migration. As opposed to direct forward modeling, we do not have to precisely know all the true model parameters to actually perform the demigration process. Neither the true velocity distribution in the earth, nor the source wavelet nor, above all, the position of the reflecting interfaces have to be known in order to apply a demigration. All that is needed, apart from the seismic image section to be demigrated, is the macrovelocity model that has been used for the migration process which produced the migrated section.

From corresponding arguments as for Kirchhoff migration, a structurally equivalent integral can be set up for its inverse operation called demigration (Hubral et al., 1996; Tygel et al., 1996). The idea is to stack along a certain surface in the depth-migrated data volume in such a way that any migrated event that possibly pertains to a certain, fixed data point $N = (\xi, t)$ in the unmigrated section is summed up. This process is represented by the Kirchhoff demigration integral

$$D(\xi, t) = \frac{1}{2\pi} \iint_E d^2x \; W_D(x, \xi, t) \;\; \partial_z M(x, z)|_{z=\zeta(x,\xi,t)} \;, \tag{3}$$

where $D(\xi, t)$ denotes the *demigrated data* and $M(x, z)$ represents the depth-migrated section as obtained from a previous true-amplitude migration, although not necessarily of Kirchhoff-type. Moreover, $W_D(x, \xi, t)$ is again a true-amplitude weight function to treat amplitudes correctly. Like the one in Kirchhoff forward modeling, also this weight function consists of an obliquity factor and the Green's function amplitudes along the two ray branches from the source and the receiver to the depth point under consideration. Also, $E$ is the spatial aperture of demigration. The stacking surface, $z = \zeta(x, \xi, t)$, is implicitly given by

$$t = \tau(\xi, x, z = \zeta(x, \xi, t)) = T(S(\xi), P) + T(G(\xi), P) \;, \tag{4}$$

i.e., again by the very same sum of traveltimes (2) as used in Kirchhoff forward modeling (1). As in Kirchhoff modeling, $S(\xi)$ and $G(\xi)$ are the points of the fixed source-receiver pair. Other than in that case, however, $P = (x, z)$ does not vary along the reflector $z = \Sigma_R(x)$ but along the surface $z = \zeta(x, \xi, t)$ defined by equation (4) under the condition that $t$ is a given, fixed constant. In other words, $z = \zeta(x, \xi, t)$ describes the surface of equal reflection time or *isochrone* pertaining to the fixed source-receiver pair $S$ and $G$ and a given time $t$. This isochrone plays the same role in Kirchhoff demigration (3) as the diffraction-time surface does in Kirchhoff migration. In both cases, the stacks sum up all contributions that come from the Fresnel zones surrounding the specular reflection points.

Let us now assume that the depth-migrated section $M(x, z)$ consists of the image of one target reflector. As shown in Tygel et al. (1994b), this image can be represented in the form

$$M(x, z) = \mathcal{R}(P) \; F[\mathcal{S}(x)(z - \Sigma_R(x))] \tag{5}$$

where $\mathcal{R}(P)$ is the reflection coefficient of the specular reflection at $P$, $F[t]$ is the source pulse, and $\mathcal{S}(x)$ is the stretch the pulse suffers in a previous migration process. As we will see below, this stretch factor will play an important role when demigration is used as a modeling algorithm. Using equation (5), the above demigration integral (3) can be written as

$$D(\xi, t) = \frac{1}{2\pi} \iint_E d^2x \; W_D(x, \xi, t) \; \mathcal{R}(P) \;\; \partial_z F[\mathcal{S}(x)(z - \Sigma_R(x))]|_{z=\zeta(x,\xi,t)} \;, \tag{6}$$

Note the obvious similarities and differences between this form of the Kirchhoff demigration integral and the above Kirchhoff modeling integral (1).

Like Kirchhoff migration, also Kirchhoff demigration does not depend on the number and location of primary reflections or reflector images. The demigrated section will thus be a superposition of all demigrated reflector images (i.e., primary reflection events) in the same way as the final image after a Kirchhoff migration is the superposition of all migrated images of all reflectors.

## Comparison

The comparison of the above two expressions (1) and (3) shows that they are very similar. Apart from the different stacking surfaces, we observe, however, two additional conceptual differences between the two integrals. First, there is a slight difference between the two weight functions. The obliquity factor of the Kirchhoff modeling integral is computed with respect to the reflector normal and the one of the Kirchhoff demigration integral with respect to the isochrone normal. This is not a major difference as at the stationary point of both integrals, i.e., at the specular reflection point on the reflector, both obliquity factors are identical. However, there is another, more basic difference. This is the stretch factor $\mathcal{S}(x)$ that appears in the argument of the source pulse in the demigration integral, but does not appear at the corresponding position in the modeling integral. It was shown by Tygel et al. (1995) that the pulse stretch caused by demigration is the inverse to that introduced by migration. In other words, Kirchhoff demigration needs this stretch factor to "unstretch" the seismic signal by the same factor $\mathcal{S}(x)$ by which Kirchhoff migration stretches it. Hence, after Kirchhoff migration and demigration, no overall stretch factor remains in the resulting reconstructed data. On the other hand, Kirchhoff forward modeling need not incorporate a stretch factor because it is *not* an inverse to a migration process but an independent (approximate) solution of the wave equation.

## Asymptotic inverses

For a certain given laterally inhomogeneous velocity model, we may construct synthetic seismic primary-reflection data using Kirchhoff forward modeling as described by integral (1). If we apply Kirchhoff migration to these synthetic data using the true velocity model, then the migration result will correctly image all model reflectors together with their corresponding reflection coefficients. Ideally, we would like to have Kirchhoff migration reconstruct the original model, i.e., we would like migration to be an (asymptotic) inverse to forward modeling. However, this is not the case. To actually reconstruct the physical model, we need to *add another process, usually called inversion,* to identify the reflector locations and extract the model parameters from the migrated section. We may then say that only the combined process of migration/inversion is a complete (asymptotic) inverse to modeling.

On the other hand, we may apply Kirchhoff migration to some given field data, and then Kirchhoff demigration to the resulting migrated section, using the same macrovelocity model in both operations. Then, the demigration result can be expected to closely reconstruct the primary reflections of the original field data, Thus, Kirchhoff demigration can be conceived as an (asymptotic) inverse to Kirchhoff migration.

From the above observations and speaking in an asymptotic sense, we conclude that Kirchhoff modeling and demigration are two processes that are closely related but not identical. Whereas Kirchhoff demigration is the inverse process to Kirchhoff migration, Kirchhoff modeling is the inverse operation to Kirchhoff migration/inversion. Nevertheless, the Kirchhoff demigration integral (3) can be employed for modeling purposes. In order to use Kirchhoff demigration in a process equivalent to Kirchhoff modeling, we obviously have to add another process, which has to be a kind of "inverse operation to seismic inversion." How this can be done is investigated in detail in the next section.

## Modeling by demigration

After we have answered the question in the title of this paper, let us briefly address another inherent question: Can we make use of the demigration procedure for modeling purposes? The answer is: Yes, we can. For a given subsurface model, we have to appropriately *simulate* a corresponding depth-migrated section *as if* obtained from a previously applied Kirchhoff migration. In other words, given the source and receiver positions, the reflector location within the velocity model, as well as the source signal to be employed, we have to construct an *artificial migrated section.* This is done by placing the *correctly amplified and stretched* source pulse into a seismic image along the reflector. Application of demigration to such an artificial migrated section leads to a "demigrated" section that is, in the high-frequency approximation, completely equivalent to the result of the Kirchhoff modeling integral.

For technical reasons, we have to distinguish between modeling for zero or finite offsets. For zero-offset modeling, the above-explained idea of modeling by demigration can be directly applied. All necessary quantities to construct the migrated image for each reflector are physical parameters directly available from the a-priori specified Earth model.

For nonzero offsets, the stretch factor as well as the reflection coefficient at the specular reflection point depend on the reflection angle of the specular reflected ray between $S(\xi)$ and $G(\xi)$. This means, of course, that for each different source-receiver pair in the considered measurement configuration, a differently scaled and stretched wavelet is to be used because the reflection angle differs. Although this angle is not available without previously determining the reflection ray between $S(\xi)$ and $G(\xi)$, it can be obtained *during* the demigration process using the already computed Green's functions. In this way, the amplitude and stretch factors are correctly determined, although the artificial migrated section is actually never explicitly constructed. Its construction is realized implicitly by the use of the location and form of the true-amplitude target reflector image and the source wavelet during the stack at each point on the isochrone (for details, see Santos et al., 1998).

## Numerical example

To demonstrate that seismic demigration is indeed different from seismic forward modeling, but still can be used for modeling purposes, we have performed the following numerical example. We consider a single seismic common-shot experiment performed over the model depicted in Figure 1. This is a simple model in which a single trough-shaped reflector separates two homogeneous acoustic media. The velocity above the reflector is 2.5 km/s and below 2.8 km/s. The source is at a position with coordinate $x = -700$ m and the receivers cover an offset range from 0 m to 3000 m. The source pulse is a Ricker wavelet with an approximate duration of

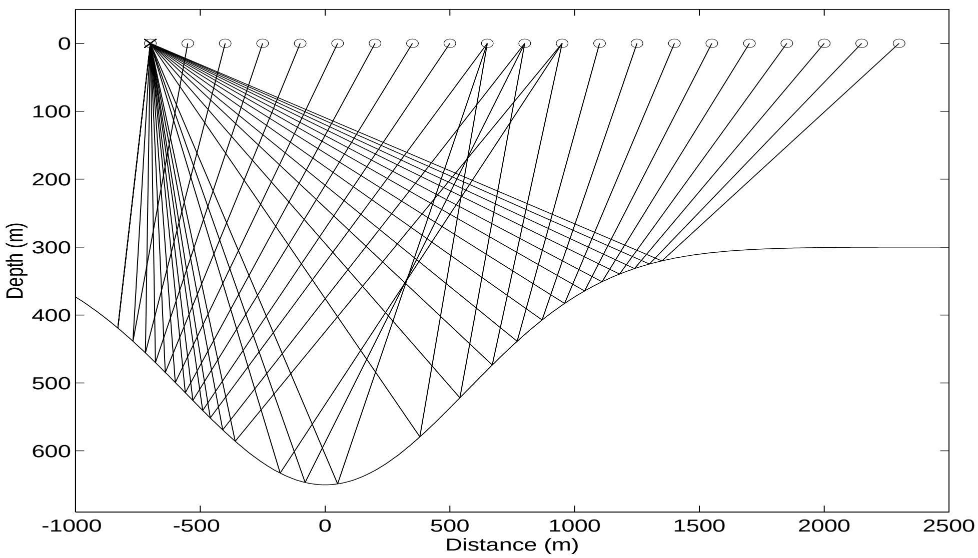


Figure 1: Model and ray family for the numerical common-shot experiment.

128 ms, i.e., a dominant frequency of about 16 Hz. Moreover, the model is assumed to be symmetric with respect to the out-of-plane $y$-direction. All sources and receivers lie in the plane $y = 0$, such that the wave propagation remains in-plane. In other words, we assume a 2.5-D situation. The advantage of 2.5-D forward modeling is that actual 3-D wave propagation effects can be modeled using fast and simple 2-D in-plane computations only. Although simple, this trough model is interesting because the wave propagation involves a caustic region which can be problematic for many modeling schemes. The size of the caustic region can be estimated from the ray family pertaining to the chosen acquisition geometry that is also shown in Figure 1.

The corresponding synthetic seismogram sections as obtained by different modeling schemes are depicted in Figure 2. Figure 2a shows the synthetic seismograms as obtained from conventional zero-order ray theory. We observe, as usual, good modeling results for the specularly reflected events in any part of the model except of the region close to the caustic. As expected, the amplitudes of the wavefield in the caustic are overestimated and the diffractions at the tails of the bow-tie structure are not modeled. In Figure 2b, we see the corresponding seismograms as obtained from Kirchhoff forward modeling using the above integral (1). The synthetic seismograms are quite similar to those of ray theory where the latter is expected to provide good results. Note, however, the significantly lower amplitudes in the post-critical region. Additionally, the Kirchhoff seismograms provide a good approximation of the wavefield in the caustic region and even a good first-order estimate of the diffraction tails.

We next consider the application of modeling by demigration, which requires the construction of an artificial migrated section to replace the given model. If this artificial migrated

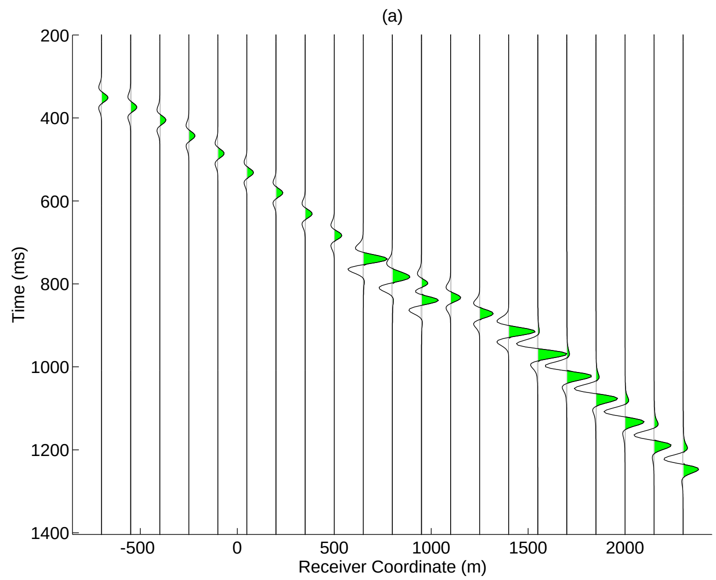


Figure 2a: Synthetic seismograms as obtained by zero-order ray theory.

section is constructed by simply attaching an unstretched seismic pulse along the reflector (as could be done for Kirchhoff forward modeling), then, the application of the demigration operator leads to the seismogram of Figure 2c. Note the severe discrepancies of the wavelet's shape for farther offsets in comparison to the correct synthetic data of Figure 2b. However, the seismogram section of Figure 2c should be identical to that of Figure 2b if demigration were equivalent to modeling, because here, the same input was used, namely (i) the specular plane-wave reflection coefficient of the incident field, (ii) the source wavelet, and (iii) the traveltime in the overburden. We observe that, in order to use demigration for modeling purposes, one must not neglect the stretch. Thus, indeed, seismic demigration is not equivalent to forward modeling.

Let us now construct the artificial migrated section by attaching to the reflector a correctly varying stretched pulse as prescribed by the theory of demigration. Then, the application of the demigration operator results in the synthetic seismogram section depicted in Figure 2d. Note that the latter one is practically identical to the result of Kirchhoff forward modeling in Figure 2b. Even the tail diffractions from the caustic bow-tie structure are modeled with the same accuracy. However, in the post-critical region, the amplitudes in Figure 2d follow more closely those in the ray-synthetic seismograms (Figure 2a).

Figure 3 shows the input depth sections for Kirchhoff modeling and for modeling by demigration. In Figure 3a, we see the seismic source pulse, scaled with the plane-wave reflection coefficient, but without stretch, attached to the reflector. Note the high amplitudes in the region of post-critical reflections. This is the effective input to the Kirchhoff forward modeling integral (1). Kirchhoff modeling is then realized by integrating along the reflector (indicated by

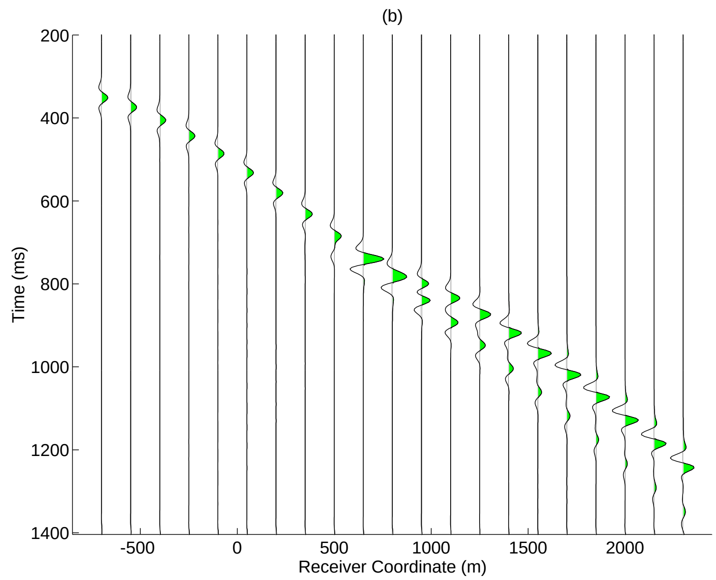


Figure 2b: Synthetic seismograms as obtained by Kirchhoff forward modeling.

a solid line) in order to construct the synthetic seismograms of Figure 2b. If we use demigration on this depth section, we get the synthetic seismograms of Figure 2c which do not exhibit correctly modeled seismic reflection events. It is, in fact, the *artificial migrated section* shown in Figure 3b that is the correct input depth section for modeling by demigration. Observe the wavelet with varying stretch attached to the reflector. Only using this artificial migrated section, demigration can be used for modeling purposes. The synthetic reflection seismograms are then obtained by stacking along isochrones like the three indicated ones for a receiver at an offset of 2000 m.

Note that it is a section like the one of Figure 3b that would be obtained by a common-shot true-amplitude Kirchhoff depth migration applied to the synthetic data of Figure 2b. The behavior of the pulse stretch is as described by Tygel et al. (1994b). Let us stress once more that this artificial migrated section is never actually constructed in the modeling-by-demigration process. It is shown here for didactical reasons only and has been computed independently.

## Modeling or demigration

Although the two integrals describing Kirchhoff forward modeling and Kirchhoff demigration both appear to be inverses to Kirchhoff migration in an asymptotic sense, we have seen that they do not exactly coincide. Their relationship was recently investigated by Jaramillo and Bleistein (1997). By using high-frequency asymptotic arguments, they have shown that the

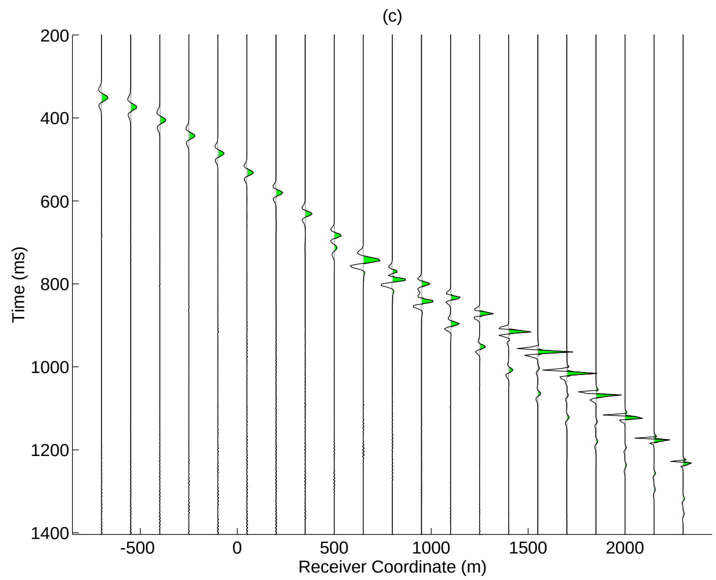


Figure 2c: Synthetic seismograms as obtained by direct demigration applied to the depth section in Figure 3a.

Kirchhoff modeling integral can be actually transformed into the Kirchhoff demigration integral. To the leading order, one may, thus, interpret the demigration integral as a nothing else but a "reorganized Kirchhoff modeling integral." However, apart from the practical realization, also the physical interpretation of this new integral is different. Unlike the Huygens' secondary source contributions in the Kirchhoff integral, it is now the individual Fresnel zone contributions to each primary reflection that are summed up by the integration (Schleicher et al., 1997).

What are, then, the advantages of implementing a seismic modeling scheme using the Kirchhoff demigration integral instead of the conventional Kirchhoff modeling integral? Well, in fact, there exist several reasons:

- The actual process of true-amplitude Kirchhoff demigration is, structurely, very similar to true-amplitude Kirchhoff migration. Therefore, existing migration programs (which are nowadays, of course, highly developed and very effective) can be readily modified to include demigration. The latter, as we have seen above, can then also be used for seismic forward modeling.

- Demigration is a process that becomes more and more important in the seismic processing sequence. Its main objective is to verify and improve the macrovelocity model. Thus, seismic modeling can be done with a software that is also useful for reflection-imaging purposes and thus already available. There is no need for an additional independent seismic forward modeling program.

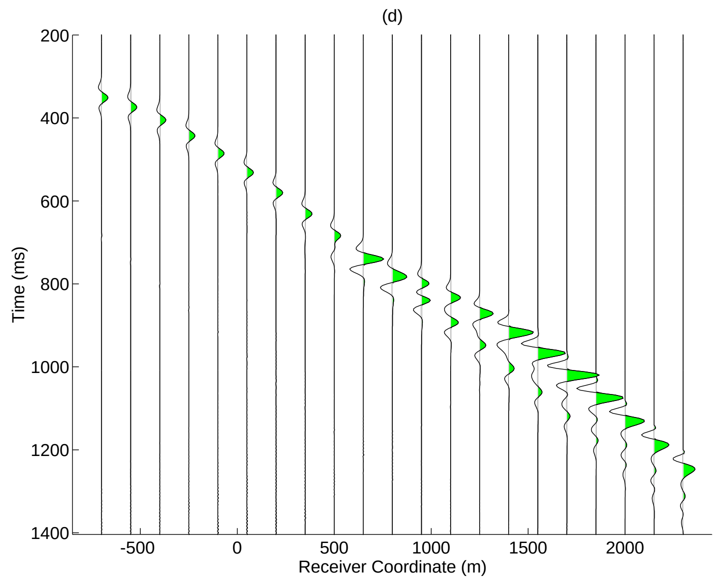


Figure 2d: Synthetic seismograms as obtained by correct modeling by demigration applied to the depth section in Figure 3b.

- For an identical macrovelocity model, migration, demigration, and modeling by demigration need the same Green's functions. This implies that, once any one of the three processes has been applied to some data for a given macrovelocity model, the remaining two will become significantly less expensive.

- Modeling by demigration turns out to be particularly advantageous when the effects of small reservoir changes are to be modeled, as is the case in 4-D or time-lapse imaging. As only the reflector properties change, but not the overburden macrovelocity model, the same Green's functions can be used several times, thus making modeling by demigration less expensive than other schemes that have to start all over again.

- As demigration is a stacking process, it "smoothes" the simulated reflection responses (in contrary to, e.g., standard ray theory that computes arrival times and amplitudes along specular rays only and thus produces sharp shadow boundaries). Thus, there is no need for constructing smooth reflectors (e.g., by applying splines) or explicit two-point ray tracing. Modeling by demigration can be directly applied to the conventionally picked reflectors that are usually a sequence of planar reflector elements. This will not cause any damage to the simulated reflection response.

- Whereas Kirchhoff modeling needs an integration along the reflector and, thus, has to be applied to each reflector independently, demigration uses as its input a depth-migrated section. Therefore, it needs just to be applied only once to model primary reflections for a whole set of different subsurface reflectors.

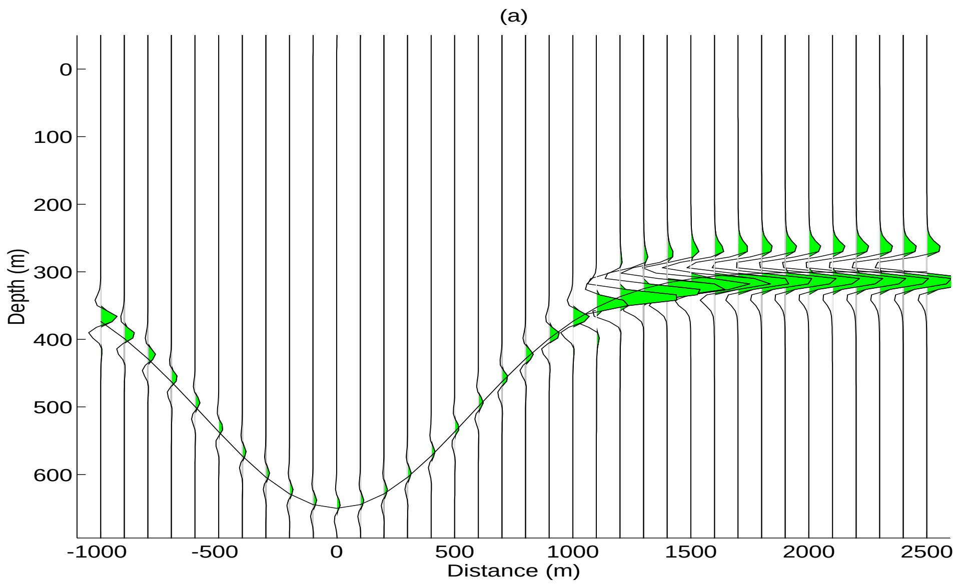


Figure 3a: Input section for Kirchhoff forward modeling. The *unstretched* source wavelet is attached to the reflector.

- Due to the limited extent of an isochrone, the stacking aperture of modeling by demigration will, in general, be smaller than that of Kirchhoff forward modeling.
- Because the demigration integral sums only contributions from the actual Fresnel zone surrounding each specular reflection point, the stacking aperture can be even further reduced.

It should be kept in mind, however, that Kirchhoff demigration is a process as expensive as Kirchhoff migration. It may, thus, be disadvantageous in comparison to other seismic modeling schemes when applied only once for a given velocity model or for a few reflectors only. Moreover, modeling by demigration can, at the present stage, provide primary reflections only. The description of multiples by this process has not been investigated yet.

## Conclusions

In this paper, we have discussed the properties of a new seismic imaging process called demigration. Kirchhoff demigration is based on the same assumptions as Kirchhoff migration. It is realized in a completely analogous way by a weighted stack of migrated data along constant-reflection-time surfaces. This process has been introduced in the seismic literature as the most natural inverse process to migration (Hubral et al., 1996; Tygel et al., 1996). We have shown that although closely related, seismic demigration is not identical to seismic forward modeling.

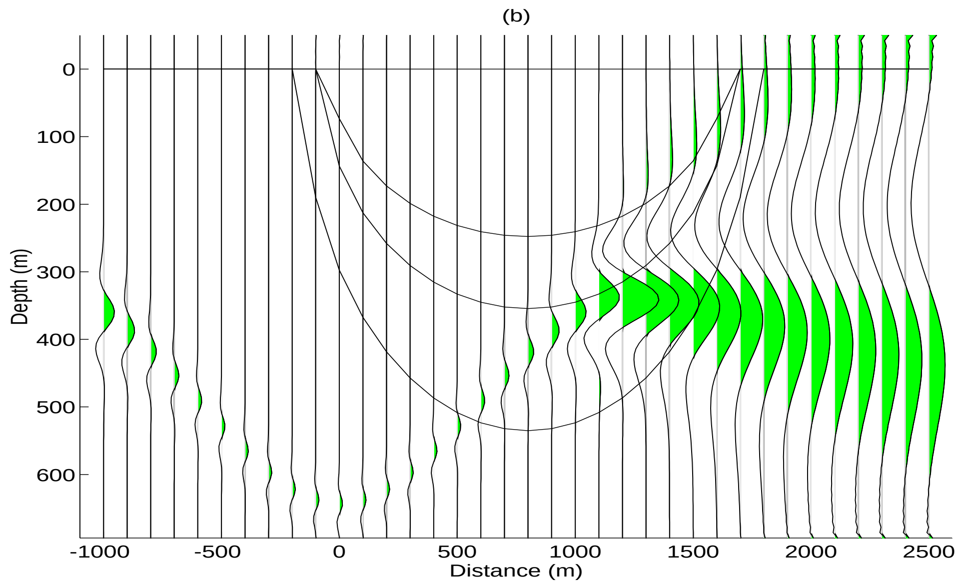


Figure 3b: Input section for modeling by demigration. The *correctly stretched* source wavelet is attached to the reflector.

With this in mind, we have to revise the widespread and commonly accepted belief that “seismic migration is the inverse process to seismic forward modeling.” We have seen that it is not forward modeling but seismic demigration that deserves to be called the “inverse of seismic migration.” The true inverse to forward modeling is, in turn, the process of migration/inversion.

Although not identical to modeling, seismic demigration can be very conveniently used for this purpose. For a given subsurface model, the modeling process consists, in principle, of two steps, namely (i) transforming the model into a fictitious, true-amplitude depth-migrated section and of (ii) applying to this artificially generated migrated section a true-amplitude demigration. In the actual implementation, the construction of the artificial migrated section is done implicitly thus combining the two steps. In this way, the new modeling technique called “modeling by demigration” is, in fact, a one-step process.

Because the stacking procedure employed in modeling by demigration is independent of the reflector shape, the new method will provide good-quality synthetic primary-reflection data even for nonsmooth reflectors. Also, because of its structure in the use of the macrovelocity model, modeling by demigration seems to be particularly appropriate for 4-D or time-lapse applications. First tests for simple Earth models confirm these observations (Santos et al., 1997).

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*Section :* Numerical Modeling
*Area of applications :* Geophysics
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