## Appendix

### Application of the $\Delta g$ method

We apply a transformation on the crystal lattice of magnetite (MT) to bring the selected nearly coincident diffraction spots of magnetite ($\boldsymbol{g}_{\mathrm{MT}i}$) into coincidence with the corresponding diffraction spots of plagioclase ($\boldsymbol{g}_{\mathrm{PL}i}$). This transformation is expressed as a transformation matrix $\mathbf{A}^{*}_{\mathrm{II}}$, where $|^{*}$ refers to reciprocal space. Prior to applying the transformation to the crystal lattice of magnetite, the magnetite and plagioclase unit cells need to be expressed in accordance with a common orthonormal coordinate system *Oxyz* in units of Å. The base vectors of the orthonormal coordinate system are **i**, **j**, **k**, which are along the *Ox*-, *Oy*- and *Oz*-axes. The crystal coordinates of magnetite and plagioclase are defined by the lattice constants $a$, $b$, $c$, $\alpha$, $\beta$, $\gamma$ with the base vectors **a**, **b**, **c**. The convention for aligning the crystal coordinate system to the orthonormal coordinate system is $\mathbf{a} \parallel Ox$ and $\mathbf{a} \times \mathbf{c} \parallel Oy$. The crystal coordinate vectors **a**, **b**, and **c** can then be denoted in orthogonal coordinates **i**, **j**, **k** by

$$\begin{aligned}\mathbf{a} &= \mathbf{i}s_1^1 + \mathbf{j}s_1^2 + \mathbf{k}s_1^3\\ \mathbf{b} &= \mathbf{i}s_2^1 + \mathbf{j}s_2^2 + \mathbf{k}s_2^3\\ \mathbf{c} &= \mathbf{i}s_3^1 + \mathbf{j}s_3^2 + \mathbf{k}s_3^3\end{aligned}$$

and in matrix notion

$$\mathbf{u}^{\mathrm{T}} = \mathbf{u}^{\mathrm{T}}_{(\mathrm{orth})} \cdot \mathbf{S}$$

where $\mathbf{u}$ represents the array of the base vectors of the crystal coordinate and $\mathbf{u}_{(\mathrm{orth})}$ represents the array of the base vectors of the orthogonal coordinate system. $|^{\mathrm{T}}$ indicates a transpose operation over the array. Matrix **S** is composed of three column vectors that are the unit vectors in the crystal coordinate system expressed as linear combinations of the base vectors of the orthonormal coordinate system,

$$\mathbf{S} = \begin{pmatrix} s_1^1 & s_2^1 & s_3^1 \\ s_1^2 & s_2^2 & s_3^2 \\ s_1^3 & s_2^3 & s_3^3 \end{pmatrix}$$

The coefficients of matrix **S** can be obtained from the scalar products of the base vectors in crystal coordinates using the orthogonality of the base vectors in the orthonormal coordinate system (Bollmann & Nissen 1968), and are written as

$$\mathbf{S} = \begin{pmatrix} a & b \cdot cos\gamma & c \cdot cos\beta \\ 0 & (b/sin\beta)(sin^2\beta - cos^2\alpha - cos^2\gamma + cos\alpha \cdot cos\beta \cdot cos\gamma)^{1/2} & 0 \\ 0 & (b/sin\beta)(cos\alpha - cos\beta \cdot cos\gamma) & c \cdot sin\beta \end{pmatrix}$$

We inserted the lattice constants of magnetite and plagioclase from Fleet (1981) and Wenk et al. (1980), respectively, into the equation above to obtain $\mathbf{S}_{\mathrm{MT}}$ and $\mathbf{S}_{\mathrm{PL}}$. The cubic magnetite has the lattice constant $a_{\mathrm{MT}}$ = 8.397 Å, and the triclinic plagioclase has the lattice constants $a_{\mathrm{PL}}$ = 8.1736 Å, $b_{\mathrm{PL}}$ = 12.8736 Å, $c_{\mathrm{PL}}$ = 7.1022 Å, $\alpha_{\mathrm{PL}}$ = 93.462°, $\beta_{\mathrm{PL}}$ = 116.054°, $\gamma_{\mathrm{PL}}$ = 90.475°. A column vector **v** in the crystal coordinate system can thus be expressed in the orthonormal coordinate as $\mathbf{v}_{(\mathrm{orth})} = \mathbf{S} \cdot \mathbf{v}$.

In the next step, the transformation matrix $\mathbf{A}_{\mathrm{II}}^*$ is applied to the magnetite to make the selected pairs of diffraction spots coincident, i.e. $\boldsymbol{g}_{\mathrm{MT}i}$ with the corresponding $\boldsymbol{g}_{\mathrm{PL}i}$. The application can be described as

$$\mathbf{A}_{\mathrm{II}}^* \cdot (\mathbf{S}_{\mathrm{MT}}^* \cdot \mathbf{G}_{\mathrm{MT}}) = \mathbf{S}_{\mathrm{PL}}^* \cdot \mathbf{G}_{\mathrm{PL}}$$

where $\mathbf{S}^* = (\mathbf{S}^{\mathrm{T}})^{-1}$, which corresponds to **S** in reciprocal space. $\mathbf{G}_{\mathrm{MT}}$ is a $3 \times 3$ matrix consisting of three non-coplanar magnetite lattice vectors in reciprocal space $\mathbf{G}_{\mathrm{MT}}$ = $(\boldsymbol{g}_{\mathrm{MT}I}, \boldsymbol{g}_{\mathrm{MT}II}, \boldsymbol{g}_{\mathrm{MT}III})$, where

$$\boldsymbol{g}_{\mathrm{MTI}} = \begin{pmatrix} -1 \\ 1 \\ 3 \end{pmatrix}, \boldsymbol{g}_{\mathrm{MTII}} = \begin{pmatrix} 2 \\ -2 \\ 2 \end{pmatrix}, \boldsymbol{g}_{\mathrm{MTIII}} = \begin{pmatrix} 0.1667 \\ 0.1667 \\ 0 \end{pmatrix}$$

the third vector $\mathbf{g}_{\mathrm{MTIII}}$ corresponds to MT[330] expressed in reciprocal space by the following procedure: (i) express MT[110] in reciprocal space, which yields MT(0.5, 0.5, 0) holding the same direction and the same magnitude; (ii) the reciprocal vector MT(0.5, 0.5, 0) is then divided by 3 to adjust the length to MT[330]. Likewise, $\mathbf{G}_{\mathrm{PL}}$ is a 3 × 3 matrix consisting of three plagioclase lattice vectors in reciprocal space. $\mathbf{G}_{\mathrm{PL}} = (\boldsymbol{g}_{\mathrm{PL}I}, \boldsymbol{g}_{\mathrm{PL}II}, \boldsymbol{g}_{\mathrm{PL}III})$, where

$$\boldsymbol{g}_{\mathrm{PLI}} = \begin{pmatrix} 3 \\ -1 \\ 0 \end{pmatrix}, \boldsymbol{g}_{\mathrm{PLII}} = \begin{pmatrix} 1 \\ 5 \\ 0 \end{pmatrix}, \boldsymbol{g}_{\mathrm{PLIII}} = \begin{pmatrix} -0.1010 \\ -0.0218 \\ 0.2000 \end{pmatrix}$$

The third vector $\boldsymbol{g}_{\mathrm{PL}III}$ corresponds to PL[005] in reciprocal space, which is obtained by the same procedure as described for $\boldsymbol{g}_{\mathrm{MT}III}$. The transformation matrix $\mathbf{A}^*_{\mathrm{II}}$ is then obtained from

$$\mathbf{A}^*_{\mathrm{II}} = \mathbf{S}^*_{\mathrm{PL}} \cdot \mathbf{G}_{\mathrm{PL}} \cdot (\mathbf{S}^*_{\mathrm{MT}} \cdot \mathbf{G}_{\mathrm{MT}})^{-1}$$

and lastly the transformation matrix $\mathbf{A}_{\mathrm{II}} = ((\mathbf{A}^*_{\mathrm{II}})^{-1})^{\mathrm{T}}$, which yields

$$\mathbf{A}_{\mathrm{II}} = \begin{pmatrix} -0.4804 & -0.1390 & 0.8252 \\ 0.6693 & -0.6693 & 0.2869 \\ 0.5499 & 0.7170 & 0.4029 \end{pmatrix}$$

The matrix $\mathbf{S}^{\mathrm{c}}_{\mathrm{MT}}$ of the constrained magnetite is obtained from

$$\mathbf{S}^{\mathrm{c}}_{\mathrm{MT}} = \mathbf{A}_{\mathrm{II}} \cdot \mathbf{S}_{\mathrm{MT}}$$

and the result reads

$$\mathbf{S}^{\mathrm{c}}_{\mathrm{MT}} = \begin{pmatrix} -4.0321 & -1.1669 & 6.9269 \\ 5.6185 & -5.6185 & 2.4079 \\ 4.6158 & 6.0184 & 3.3819 \end{pmatrix}$$

The lattice constants of the constrained magnetite $\mathrm{MT^c}$ unit cell can be calculated from $\mathbf{S}^{\mathrm{c}}_{\mathrm{MT}}$. The constrained base vector $\boldsymbol{a}^{\mathrm{c}}_{\mathrm{MT}} = \mathbf{S}^{\mathrm{c}}_{\mathrm{MT}} \cdot [100]'$, which corresponds to the first column in $\mathbf{S}^{\mathrm{c}}_{\mathrm{MT}}$. The value of the base vector $a^{\mathrm{c}}_{\mathrm{MT}} = 8.3145$ Å is the new lattice constant of the constrained magnetite. Similarly, $\boldsymbol{b}_{\mathrm{MT}}^{\mathrm{c}} = \mathbf{S}_{\mathrm{MT}}^{\mathrm{c}} \cdot [010]'$ and $\boldsymbol{c}_{\mathrm{MT}}^{\mathrm{c}} = \mathbf{S}_{\mathrm{MT}}^{\mathrm{c}} \cdot [001]'$. The angle between the base vectors $\boldsymbol{b}_{\mathrm{MT}}^{\mathrm{c}}$ and $\boldsymbol{c}_{\mathrm{MT}}^{\mathrm{c}}$ of the constrained magnetite thus define the angle $\alpha_{\mathrm{MT}}^{\mathrm{c}} = \measuredangle(\mathbf{b}_{\mathrm{MT}}^{\mathrm{c}},\ \mathbf{c}_{\mathrm{MT}}^{\mathrm{c}})$, and is calculated from the inverse tangent formula $\alpha_{\mathrm{MT}}^{\mathrm{c}} = \mathrm{atan2}(\left\|\mathbf{b}_{\mathrm{MT}}^{\mathrm{c}} \times \mathbf{c}_{\mathrm{MT}}^{\mathrm{c}}\right\|,\ \mathbf{b}_{\mathrm{MT}}^{\mathrm{c}} \cdot \mathbf{c}_{\mathrm{MT}}^{\mathrm{c}})$. $\beta_{\mathrm{MT}}^{\mathrm{c}}$ and $\gamma_{\mathrm{MT}}^{\mathrm{c}}$ are obtained following the same procedure. The lattice constants of the constrained magnetite are shown in Table 3. The $\mathrm{MT}^{\mathrm{c}}$ unit cell only slightly differs from the unit cell of unconstrained magnetite.