The free energy per site $f \equiv -(k_B T/N) \ln Z$ for a given $M$ is therefore, in the mean field approximation,

$$f_{MF}(H) = \tfrac{1}{2} J M^2 - \beta^{-1} \ln \cosh \beta(JM + H), \tag{1}$$

apart from an irrelevant constant. At this point, the free energy density is not a function of the magnetisation $M$, rather, it is a function of the external field $H$. The field $H$ may be thought of as a source for the spin variables $s(r)$ so that $\ln Z(H)$ is the generating functional of connected correlation functions. The magnetisation is given by

$$M(H) = \frac{1}{N} \sum_r \langle s(r) \rangle_H = (\beta N)^{-1} \frac{d}{dH} \ln Z(H) = -\frac{df}{dH}, \tag{2}$$

where the subscript is just a reminder that the expectation value is in the presence of the source. Since $\ln Z(H)$ is a convex function of $H$, its derivative is monotonic. Therefore, $M(H)$ may be inverted to yield a function $H(M)$ that gives the value of the external field needed to attain a given expectation value $M$ of the spin variables. In our mean field approximation,

$$M = \tanh \beta(JM + H) \implies H = -JM + \beta^{-1} \tanh^{-1} M. \tag{3}$$

The effective potential $\tilde{f}(M)$, also known as the Gibbs free energy, is the minimum energy (per site) within the space of spin configurations that have a given expectation value $M$. It is obtained via Legendre transform,

$$\tilde{f}(M) = f(H) + H(M) M. \tag{4}$$

Note that $d\tilde{f}/dH = 0$ as desired. The correct variational free energy in the mean field approximation is

$$\tilde{f}_{MF}(M) = -\tfrac{1}{2} J M^2 - \beta^{-1} \ln \left( \frac{1}{\sqrt{1 - M^2}} \right) + \beta^{-1} M \tanh^{-1} M. \tag{5}$$

Notice that the extrema of $\tilde{f}_{MF}$ are given by $M = \tanh(\beta J M)$, which is just eq. (2.8) in the book. To restore a real external magnetic field, simply write $H$ in (3) as $H + H_0$. But for $H_0 = 0$ and small $M$, $\tilde{f}_{MF}$ has a Taylor expansion

$$\tilde{f}_{MF} = \text{const.} + \tfrac{1}{2}(k_B T - J) M^2 + \tfrac{1}{12} \beta^{-1} M^4 + O(M^6). \tag{6}$$

The coefficient of the $M^4$ term is positive. Depending on the sign of the quadratic term, the shape of the graph is one of those shown in Figure 2.1 in the book.